EVALUATION OF THE MINERAL STATUS OF GRAZING RUMINANTS IN SOUTH SULAWESI, INDONESIA

BY

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS ii

LIST OF TABLES vii

ABSTRACT xi

CHAPTERS

I INTRODUCTION 1

II LITERATURE REVIEW 5

Characterization of Large Ruminant Production in South Sulawesi, Indonesia 5
Mineral Status of Soils 8
  Soil Macrominerals 9
  Soil Microminerals 12
Mineral Status of Plants 15
  Plant Macrominerals 15
  Plant Microminerals 18
Mineral Status of Ruminants 22
  Blood Minerals 23
  Liver Minerals 28
  Bone Minerals 31

III MATERIALS AND METHODS 33

Description of Research 33
Sample Collection 35
  Soil Samples 35
  Forage Samples 36
  Animal Tissue Samples 37
Chemical Analysis 38
  Soil Samples 38
  Forage Samples 39
  Animal Tissue Samples 40
Statistical Analysis 41

Page

IV MINERAL STATUS OF GRAZING CATTLE IN SOUTH SULAWESI, INDONESIA. I. MACROMINERALS 46

- Introduction 46
- Experimental Procedure 47
- Results and Discussion 49
  - Soil Analyses 49
  - Forage Analyses 54
  - Animal Tissue Analyses 60
    - Blood 60
    - Bone 64
  - Relationship of Minerals 69
- Summary 70

V MINERAL STATUS OF GRAZING CATTLE IN SOUTH SULAWESI, INDONESIA. II. MICROMINERALS 72

- Introduction 72
- Experimental Procedure 73
- Results and Discussion 75
  - Soil Analyses 75
  - Forage Analyses 79
  - Animal Tissue Analyses 85
    - Blood 85
    - Liver 89
  - Relationship of Minerals 96
- Summary 97

VI MINERAL STATUS COMPARISONS BETWEEN GRAZING CATTLE AND WATER BUFFALO IN SOUTH SULAWESI, INDONESIA 99

- Introduction 99
- Experimental Procedure 100
- Results and Discussion 102
  - Soil Analyses 102
  - Forage Analyses 105
  - Animal Tissue Analyses 110
    - Blood 110
    - Bone 115
    - Liver 119
- Summary 124

VII SUMMARY AND CONCLUSIONS 126

APPENDICES

A SUPPLEMENTARY TABLES 133

B RAW DATA 180

Page

LITERATURE CITED 206
BIOGRAPHICAL SKETCH 222

LIST OF TABLES

Table Page

1 SUBSTRATES OF GREATEST VALUE IN ASSESSING AND TRACING MINERAL DEFICIENCIES 24

2 SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MACROMINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND REGION 50

3 PERCENTAGE OF SOIL SAMPLES DEFICIENT IN MACROMINERALS 52

4 FORAGE MACROMINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND REGION 55

5 PERCENTAGE OF FORAGE SAMPLES DEFICIENT IN MACROMINERALS AND CRUDE PROTEIN 57

6 BLOOD MACROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION 61

7 PERCENTAGE OF BLOOD PLASMA AND SERUM SAMPLES DEFICIENT IN MACROMINERALS 62

8 BONE MACROMINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON AND REGION 65

9 PERCENTAGE OF BONE SAMPLES DEFICIENT IN MACROMINERALS, ASH AND SPECIFIC GRAVITY 67

10 SOIL MICROMINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND REGION 76

11 PERCENTAGE OF SOIL SAMPLES DEFICIENT IN MICROMINERALS 77

12 FORAGE MICROMINERAL CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND REGION 80

13 PERCENTAGE OF FORAGE SAMPLES DEFICIENT IN MICROMINERALS 82

Table Page

14 BLOOD SERUM MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION 86

15 PERCENTAGE OF BLOOD SERUM SAMPLES DEFICIENT IN MICROMINERALS 87

16 LIVER MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION 90

17 PERCENTAGE OF LIVER SAMPLES DEFICIENT IN MICROMINERALS 92

18 SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON 103

19 FORAGE MINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON 106

20 BLOOD MINERAL CONCENTRATIONS AS RELATED TO SEASON AND ANIMAL SPECIES 111

21 BONE MINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON AND ANIMAL SPECIES 116

22 LIVER MINERAL CONCENTRATIONS AS RELATED TO SEASON AND ANIMAL SPECIES 120

23 SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL CORRELATION COEFFICIENTS 133

24 FORAGE MINERAL CORRELATION COEFFICIENTS 134

25 BLOOD MINERAL CORRELATION COEFFICIENTS 135

26 BONE MACROMINERAL AND SPECIFIC GRAVITY CORRELATION COEFFICIENTS 138

27 CORRELATION COEFFICIENTS BETWEEN FORAGE MACROMINERALS AND SOIL ANALYSES 137

28 CORRELATION COEFFICIENTS BETWEEN BLOOD AND FORAGE MINERALS 138

29 CORRELATION COEFFICIENTS BETWEEN BONE AND FORAGE MINERALS 139

30 CORRELATION COEFFICIENTS BETWEEN BLOOD AND BONE MINERALS 140

Table Page

31 LIVER MICROMINERAL CORRELATION COEFFICIENTS 141

32 CORRELATION COEFFICIENTS BETWEEN FORAGE MICROMINERALS AND SOIL ANALYSES 142

33 CORRELATION COEFFICIENTS BETWEEN LIVER AND FORAGE MINERALS 143

34 CORRELATION COEFFICIENTS BETWEEN BLOOD AND LIVER MINERALS 144

35 SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL PARTIAL CORRELATION COEFFICIENTS 145

36 FORAGE MINERAL PARTIAL CORRELATION COEFFICIENTS 146

37 BLOOD MINERAL PARTIAL CORRELATION COEFFICIENTS 147

38 BONE MACROMINERAL AND SPECIFIC GRAVITY PARTIAL CORRELATION COEFFICIENTS 148

39 PARTIAL CORRELATION COEFFICIENTS BETWEEN FORAGE MACROMINERALS AND SOIL ANALYSES 149

40 PARTIAL CORRELATION COEFFICIENTS BETWEEN BLOOD AND FORAGE MINERALS 150

41 PARTIAL CORRELATION COEFFICIENTS BETWEEN BONE AND FORAGE MINERALS 151

42 PARTIAL CORRELATION COEFFICIENTS BETWEEN BLOOD AND BONE MINERALS 152

43 LIVER MICROMINERAL PARTIAL CORRELATION COEFFICIENTS 153

44 PARTIAL CORRELATION COEFFICIENTS BETWEEN FORAGE MICROMINERALS AND SOIL ANALYSES 154

45 PARTIAL CORRELATION COEFFICIENTS BETWEEN LIVER AND FORAGE MINERALS 155

46 PARTIAL CORRELATION COEFFICIENTS BETWEEN BLOOD AND LIVER MINERALS 156

47 SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND DISTRICT 157

Table Page

48 FORAGE MINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND DISTRICT 159

49 BLOOD MINERAL CONCENTRATIONS AS RELATED TO SEASON, DISTRICT AND ANIMAL SPECIES 161

50 BONE MINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON, DISTRICT AND ANIMAL SPECIES 163

51 LIVER MINERAL CONCENTRATIONS AS RELATED TO SEASON, DISTRICT AND ANIMAL SPECIES 165

52 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR SOIL VARIABLES (10 DISTRICTS) 167

53 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR FORAGE VARIABLES (10 DISTRICTS) 169

54 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE BLOOD VARIABLES (10 DISTRICTS) 171

55 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE BONE VARIABLES (10 DISTRICTS) 172

56 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE LIVER VARIABLES (10 DISTRICTS) 173

57 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR SOIL VARIABLES (4 DISTRICTS) 174

58 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR FORAGE VARIABLES (4 DISTRICTS) 175

59 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE AND BUFFALO BLOOD VARIABLES (4 DISTRICTS) 176

60 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE AND BUFFALO BONE VARIABLES (4 DISTRICTS) 177

61 ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE AND BUFFALO LIVER VARIABLES (4 DISTRICTS) 178

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EVALUATION OF THE MINERAL STATUS OF GRAZING RUMINANTS IN SOUTH SULAWESI, INDONESIA

By

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A study was conducted in the province of South Sulawesi, Indonesia to determine the mineral status of grazing ruminants as the basis for a mineral supplementation program. During the rainy and dry seasons of 1987, samples of soil, forage and tissue (blood, bone, liver) of Bali cattle from ten districts, and tissue of water buffaloes from four districts within three climatic regions (Western, Central, Eastern) were collected for mineral analyses.

Phosphorus was found to be the most likely deficient mineral in soils with regional differences ($P<.01$). In both seasons, minerals most likely to be deficient in forages were phosphorus, selenium, sodium, zinc and copper. Regional differences ($P<.10$) were found for phosphorus, selenium and sodium, while seasonal variations ($P<.10$) were found for copper.

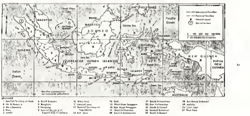
Cattle tissue analyses showed seasonal variations in serum magnesium ($P<.05$), selenium ($P<.05$) and zinc ($P<.01$), and liver cobalt ($P<.05$), copper ($P<.10$), manganese ($P<.01$) and molybdenum ($P<.10$). Regional differences were found for serum magnesium ($P<.10$), copper ($P<.05$) and selenium ($P<.01$); bone specific gravity ($P<.01$); and liver copper ($P<.01$), manganese $P<.01$), molybdenum $P<.05$), and selenium ($P<.01$) concentrations. High incidence of deficiencies were found in both seasons for bone phosphorus and calcium in all regions, and liver copper in the Western region; in the rainy season for liver manganese in the Central region; and in the dry season for serum copper in the Western region. In the dry season, liver molybdenum concentrations of cattle in the Eastern region may be considered as excessive (>4 ppm). Analyzed in four districts, cattle had higher serum ($P<.10$) and liver ($P<.05$) selenium, but lower liver cobalt ($P<.05$) and copper ($P<.10$) concentrations than buffaloes. Bone specific gravity varied ($P<.10$) due to the season by animal species interaction effect.

It is suggested that minerals most likely limiting ruminant production in South Sulawesi, Indonesia are phosphorus, copper, sodium, selenium, calcium, zinc and manganese. Variations of forage copper concentrations within all regions and some degree of molybdenum excess in the Eastern region may need special attention in formulating mineral supplements.

CHAPTER I
INTRODUCTION

Indonesia is an archipelago nation that includes more than 13,600 islands. It stretches along the equator for some 5,120 km at 6° north to 11° south latitude and 90° to 141° east longitude (Figure 1). Total land area, which accounts for less than one-third of the national territory, is estimated to be 1,920,000 km^2 (Bunge, 1983). Indonesia is generally classified as having a tropical climate with two seasons, wet (November to April) and dry (May to October), determined by two monsoon winds. These are the northwest and southeast monsoons that blow at alternate times of the year, with the northwest monsoon bringing more moisture than the southeast. The equatorial position of Indonesia keeps temperature in the archipelago relatively constant throughout the year. By contrast, precipitation fluctuates both in total annual amount and in its distribution (Adiwoso-Suprapto, 1983).

Historically, agricultural production in Indonesia has been concentrated on the highly fertile soils, and hence, the densely populated islands of Java and Bali. Increasing demand for agricultural products in the last two decades has



Source: Bunge (1983).

FIGURE 1. INDONESIA: GEOGRAPHICAL LOCATION AND ADMINISTRATIVE REGIONS

necessitated expansion of agricultural lands to the less densely populated regions of the outer islands (Ahmad, 1982). For large ruminant production, the province of South Sulawesi has been one of the primary choices. Its extensive areas of grassland have invited larger, commercial-type operations of large ruminant production into the region (Reksohadiprodjo, 1980). However, production improvements have not yet been successful (Tillman, 1981).

It has been known that undernutrition is commonly accepted as the most limiting factor to ruminant livestock production in the tropics. Occasional reports (Lebdosoekojo, 1980; Nitis, 1980; Tillman, 1981) and personal observations indicate that Indonesian ruminant livestock is no exception. For grazing ruminants, forages are the major source of essential nutrients. Only rarely, however, can tropical forages completely satisfy all of the nutrients, especially mineral requirements (McDowell, 1985a). Under these conditions, supplemental feeding could be justified for the improvement of livestock production. An efficient mineral supplementation program, however, requires information on the mineral status of animals in specific regions.

Although increasingly more attention is paid to mineral nutrition of Indonesian ruminant livestock, in South Sulawesi only a few studies on mineral status and supplementation have been conducted. Even fewer have been reported in the available literature.

The objective of this research was to provide information for the basis of an economically feasible mineral supplementation program for grazing ruminants in the province of South Sulawesi, Indonesia, by

1. establishing if specific mineral deficiencies or toxicities exist;
2. determining the season and region under which mineral deficiencies occur and, therefore, establishing the conditions in which animals are likely to respond to mineral supplementation;
3. evaluating and comparing the mineral status of beef cattle and water buffalo.

CHAPTER II
LITERATURE REVIEW

Characterization of Large Ruminant Production in South Sulawesi, Indonesia

The province of South Sulawesi is located at the southern peninsula of Sulawesi Island. This province extends from 0°12' north to 8° south latitude and from 116°48' to 122°36' east longitude and occupies 62,482 km^2 or 3.8% of the total area of Indonesia. Administratively, the province of South Sulawesi is divided into 21 districts or regencies and two municipalities (Kantor Statistik, 1985).

Muljadi (1977), as cited by Adiningsih et al. (1988), reported that the majority of land areas of South Sulawesi is covered by red yellow podzolic soils, primarily ultisols and oxisols, with fertility constraints in nutrients as well as in physical soil characteristics. Topographical profiles vary from flat in the narrow coastal plains to hilly in mountainous terrains. As a result the climate varies considerably.

In the wet season, the northwest monsoon brings precipitation to the northern and most of the western regions while the eastern region, under the rainshadow of the central mountain chain, is dry. The highest rainfall is usually recorded in January and February. The opposite pattern occurs in the dry season. The southeast monsoon brings precipitation to the eastern region while the western region is dry. The highest rainfall is recorded in May and June (LPT, 1969). According to the classification based on the quotient (Q) values, the ratio between dry and wet months (Schmidt and Ferguson, 1951), there are five rainfall types for regions of South Sulawesi. These are type A (Q = 0 to .14), type B (Q = .14 to .33), type C (Q = .33 to .60), type D (Q =.60 to 1.50) and type E (Q = 1.50 to 1.67). Oldeman and Darmiyati (1977) described those types of rainfall, based on the number of consecutive wet (>200 mm/month) and dry (<100 mm/month) months, as follows: type A, >9 wet and <2 dry; type B, 7 to 9 wet and <2 to 4 dry, type C, 5 to 6 wet and <2 to 5 dry; type D, 3 to 4 wet and <2 to >8 dry; and type E, <3 wet and 2 to 5 dry.

Livestock has traditionally been important in South Sulawesi agriculture. Recent reports (Kanwil DeptAn, 1985) showed large ruminant populations of 1,146,562 cattle and 516,445 buffaloes, which ranked third among provinces in the nation. There are few cattle ranches operated commercially, but most of the cattle and buffaloes in South Sulawesi are owned by smallholders who may keep three to ten animals. The animals are maintained largely on grass diets by letting them graze on communal pastures during the day and feeding crop by-products in a covered stall near the house at night. Some farmers who own larger herds keep the animals on range pastures continually. Many farmers also use their animals to provide draft power in crop cultivation. Buffaloes are generally associated with cultivation in wetter regions and heavier soils, while cattle are used generally in drier areas (Ffoulkes, 1986).

The major cattle breed in South Sulawesi is Bali cattle. This breed is well accepted as draft animals and for beef production (Subandriyo et al., 1979). As draft animals, Bali cattle are easier to train and maintain their optimum reproductive performance better than other breeds. As beef producers, they are more promising than other breeds due mainly to their high adaptability to low-quality feeds but are also responsive to more optimum feeding. However, the Bali cattle found in South Sulawesi are smaller than those found in Bali island (Reksohadiprodjo, 1980). The market weight of 250 to 300 kg is achieved in three to four years. The average weight of fully-grown mature bulls is 400 kg (Payne and Rollinson, 1973; Subandriyo et al., 1979). The buffalo found in South Sulawesi is the swamp or water buffalo breed similar to those found throughout Southeast Asia. Mature male water buffaloes may weigh up to 600 kg, whereas the females weigh a little less (Tillman, 1981). It has been reported that buffalo bulls fed a high-concentrate diet may gain as well as the Ongole bulls (Moran, 1978).

However, the dressing percentage of the buffalo is lower than that of cattle.

Many services to farmers are provided by the government through the District Livestock Service. These include extension, artificial insemination, vaccination and meat inspection in the district slaughterhouses. In some districts limited veterinary services are provided by the government-employed veterinarian. The District Livestock Service has agents or field technicians in subdistricts within its territory. One of their responsibilities is, along with the subdistrict official, issuing an animal ownership or identification card. This card is required by law for obtaining the vaccination or other veterinary services and the moving permit to transport the animals and to sell them to other district territories.

Mineral Status of Soils

It is recognized that the parent rock from which a soil is formed can influence the quantity of minerals available to the plant as well as the availability of applied nutrients (Reid and Horvath, 1980). Although little relationship has been found between soil chemistry and mineral composition of native vegetation and farm crops (Hemphill, 1977), Towers and Clark (1983) indicated that mineral concentrations in both soil and plants influence the mineral status of grazing animals. A more satisfactory soil analysis using soil extracts (i.e., 0.1 N HCl or 2.5% acetic acid) which contains the more available forms of soil minerals, has been suggested by McDowell et al. (1986) to more closely relate mineral concentrations to status of livestock. However, soil analysis alone cannot be used to reliably predict mineral deficiencies in animals (Towers and Clark, 1983).

Soil Macrominerals

Both inorganic and organic forms of phosphorus occur in soil, and both are important to plants as sources of this element. The organic component, constituting 20 to 80% of the total, is inert before mineralization; after this, it contributes significantly to the phosphorus nutrition of plants (Dalal, 1977; Reid and Horvath, 1980; Brady, 1984). Most inorganic phosphorus compounds in soils fall into those containing calcium and those containing iron and aluminum (Brady, 1984). Beeson and Matrone (1976) suggested that a low availability of soil phosphorus may be due more to soil reactions such as high acidity or alkalinity, resulting in the formation of insoluble iron or aluminum phosphates or basic phosphates, than to total concentration of phosphorus in the soil. Analysis of soils, using the double-acid extraction method, indicated that a phosphorus content of 0 to 5 ppm in the soil solution is very low; 6 to 13 ppm is considered low; 14 to 25 ppm is medium; and a content of 25 to 50 ppm is very high in this element (Breland, 1976, Bahia, 1978). The extractant used was later referred to as the Mehlich I extractant by the Soil Science Society of America (Rhue and Kidder, 1983).

Most soils, except those of a sandy texture, are comparatively high in total potassium. This element is mostly fixed in the primary mineral or is found in forms that are only moderately available to plants (Rhue and Street, 1980). The greatest part, 90 to 98%, of all soil potassium in a mineral soil is relatively unavailable (Blue, 1974; Tisdale and Nelson, 1975; Rhue and Street, 1980; Schaff and Skogley, 1982). Bahia (1978), using the double-acid extraction method of soil analysis, indicated the following values as criteria for available potassium in soils: 0 to 60 ppm, low; 61 to 120 ppm, average; and greater than 120 ppm, high.

The exchangeable calcium in a soil has an important relationship with soil pH and with the availability of several elements. An excess of calcium results when carbonate precipitates, resulting in a low solubility of phosphorus, iron, manganese and zinc (Thompson and Troeh, 1978). Soil calcium deficiencies can occur in humid regions where rainfall exceeds evapotranspiration for most of the year (Kamprath and Foy, 1971). However, the calcium content of soils are poorly reflected in the calcium concentration of plants (Sillanpaa, 1982). Breland (1976) indicated that by using the double acid extraction method for analysis of Florida soils, calcium levels from 0 to 71 ppm in the soil solution are considered as low, 72 to 140 ppm as medium, and 141 ppm or more as high.

In a review of factors affecting the availability of soil magnesium, Metson (1974) stated that the amount of magnesium in the soil is strongly influenced by the process of weathering. Only a small proportion of the total magnesium present in the soil is available to the plant. Furthermore, the author concluded that the exchangeable magnesium, in part, determines availability of magnesium to the plant. On the other hand, Christenson and Doll (1978) reported that the total magnesium uptake by plants was not related to the total magnesium levels or exchangeable magnesium levels in soil. Breland (1976) reported that for Florida soils analyzed using the double-acid extraction methods, values from 0 to 9.1 ppm are low, 9.2 to 21.1 ppm magnesium are medium, and more than 21.2 ppm are high. Rhue and Kidder (1983) in a later report indicated that for agronomic and vegetable crops grown on acid soils in Florida, the amount of Mehlich I extractable magnesium is interpreted as follows: less than 30 ppm, low; from 30 to 60 ppm, medium, and more than 21.2 ppm are high.

Soils of the tropics generally have low levels of sulfur compared to those of temperate regions (Sanchez, 1976). McDowell (1985a) indicated that the incidence of sulfur deficiency in tropical countries is increasing due to the increasing use of high-analysis, low-sulfur-containing phosphorus fertilizers, the increased need for sulfur brought about by increases in yield, and practices of forage burning.

Soil Microminerals

It has been reported that few, if any, soils are deficient in total iron since the total soil iron content varies from 1,000 to 10,000 ppm (Foth and Ellis, 1988). However, the solubility of iron in soils may be limited by the low solubility of iron hydroxides and iron oxides in a pH range in which crops are grown (Lindsay, 1972). Soil conditions that lead to iron deficiency in plants include pH above 7.0, low soil moisture, and low organic matter content (Foth and Ellis, 1988).

Manganese occurs in soil in many different forms, most of which are not readily available to growing plants (Street and Rhue, 1980a). The oxidation and reduction status and soil pH are the two most important factors controlling the solubility and availability of manganese. Under reduction conditions (wet soils) manganese is solubilized while under oxidizing conditions (dry soils), it is precipitated or immobilized. The soil pH at which manganese is most available is between pH 5.0 and 6.5. Soil manganese concentrations show a wide range, from less than 20 to more than 6,000 ppm (Lindsay, 1972; Street and Rhue, 1980a). It has been known that high levels of available iron in organic soils may lead to a manganese deficiency in plants (Poth and Ellis, 1988).

Available copper is present in soils as cupric ions and some cuprous ions in primary minerals (McLaren et al., 1983). Furthermore, the author suggested factors affecting the level of copper in soils that include parent material, organic matter, clay concentration and soil pH. Sanders (1982) indicated that as pH increases, the quantity of copper adsorbed increases and the proportion of copper in solution as cupric ion decreases. It has been reported that the average copper content in agricultural soils is 20 ppm, with a range of 2 to 50 ppm (Reid and Horvath, 1980).

In general, available molybdenum is high in alkaline soils rich in organic matter and in soils derived from volcanic materials, whereas molybdenum deficiencies are associated with soil pH levels below 5.5 (Mortvedt et al., 1972; Davis, 1974). Besson and Matrone (1976) observed that soils often associated with copper-molybdenum problems in grazing ruminants are the peats, muck soils and other poorly drained soils with high organic matter content. This is thought to be due to the strong binding of copper to organic complexes. Aubert and Pinta (1977) indicated that the solubility or availability of copper tends to decrease as the pH of the soil increases, although the effects of pH on copper are not as marked as the effect on molybdenum uptake.

The solubility of zinc in soils is dependent on pH. It decreases as pH increases (Lindsay, 1972). Sanders (1983) similarly reported that extractable zinc concentration in the soil solution decreased as soil pH increased. Therefore, it has been suggested that overliming may induce a decrease in the availability of zinc and may cause a deficiency, since the solubility of zinc decreases rapidly at pH 6.0 to 7.0 (Sanchez, 1976). Street and Rhue (1980b) reported that total zinc content of Florida soils is in the range of 10 to 300 ppm, and that, generally, the extractable zinc levels increase with increasing organic matter.

As with other elements, the total selenium content of soils has shown little relationship to plant selenium concentrations. This is thought to be due to the difference in chemical forms of selenium that exist in the soils which are closely related to the oxidation-reduction potential and pH of soils, and vary widely in their solubility (Lakin, 1972). Furthermore, it has also been suggested that selenium in plants depends not only on soil factors but is also influenced by plant species, maturity, yield, and climate (Ammerman et al., 1978). However, Cary et al. (1967) have indicated that soil selenium levels of less than .5 ppm are prevalent in areas of selenium deficiency in livestock.

Mineral Status of Plants

Only a fraction of the total mineral concentration in soils is taken up by plants. McDowell et al. (1984) have summarized soil properties and conditions that can affect the uptake and utilization of minerals by crops and pastures. These include soil acidity, soil moisture or drainage, soil temperature and seasonal effects, plant genus, species and variety, as well as management and fertilization practices.

Plant Macrominerals

Phosphorus, as a major nutrient element occurring in all plants, has been considered to be the most prevalent mineral deficiency throughout the world (McDowell et al., 1984). Reid and Horvath (1980) indicated that increasing soil moisture and temperature will increase the rate of diffusion of phosphorus to the root systems, although high levels of soil-water and soil compaction could reduce the amount of oxygen in the soil and, consequently, the active uptake of phosphorus by plants. There are other factors that could affect phosphorus in plants. Gomide (1978) reported that the plant age is an important factor affecting the chemical composition and nutritive value of forages; phosphorus levels decrease with age. The main form of phosphorus in most plant sources is phytate phosphorus. Phytate combines with many elements such as calcium, magnesium, manganese and zinc, as well as phosphorus, making them, to some degree, unavailable to the animal. The molecular structure is myo-inositol hexaphosphoric acid or phytic acid (IMC, 1978). Therefore, the situation regarding the grazing animal under extensive management systems and on phosphorus-deficient soils may be considerably more critical, particularly when the phosphorus concentration in herbage declines to approximately .10 to .15% (Reid and Horvath, 1980).

Potassium is second only to nitrogen in the amount absorbed by plants. In plant tissue, it exists as the potassium ion and is completely water soluble. For this reason, potassium leaches readily from dead plants, which is why organic matter in soils tends to be low in potassium (Rhue and Street, 1980). Total and exchangeable potassium quantities are frequently low in ultisols and oxisols in the tropics, and potassium is often a neglected element in pasture fertilization. Successful production of different plant species adapted to high soil acidity has been possible when potassium deficiencies have been corrected (Blue, 1974). Since plants are relatively high in potassium, there is low probability of finding potassium deficiencies in most conventional ruminant diets. However, in tropical regions it is possible that potassium deficiencies could arise in view of the decreasing content of this mineral with increasing forage maturity during the extended dry season (McDowell et al., 1984).

In contrast to phosphorus, the calcium level in many types of vegetation generally remains relatively high throughout the year. However, calcium tends to be immobilized in older tissues so that young leaves suffer from deficiency, whereas older ones may remain normal (Hewitt and Smith, 1975). Reid and Horvath (1980) stated that calcium deficiency is rare in grazing livestock, unless the pasture contains less than .2% calcium. Underwood (1981) indicated that the lower incidence of calcium than of phosphorus disorders is attributed to the following factors: a higher concentration of calcium than phosphorus in the leaves and stems of the most plant species; a wider distribution of phosphorus-deficient than of calcium-deficient soils; and a lesser decline in concentration of calcium than of phosphorus with advancing maturation of the plant.

Magnesium is best known for its role in chlorophyll, with about 3% of the weight of chlorophyll is magnesium (Hewitt and Smith, 1975). Reid and Horvath (1980) listed some of the factors causing magnesium deficiency in plants as acid, sandy, highly leached soils; calcareous soils having low magnesium levels; high rates of nitrogen and potassium fertilization; and vegetation having high magnesium requirements. Giving the importance to fertilization management, it has been found that nitrogen fertilization increases the magnesium concentration of herbage in conditions where soil magnesium levels are not limiting (Reid and Horvath, 1980).

Sulfur has long been recognized as essential for plant and animal growth. Grady (1984) indicated that atmospheric sulfur dioxide has supplied large quantities of the element to both plants and soils. It has been reported that plants can reduce sulfate to sulfide as indicated by their growth with sulfate as the only source of sulfur, and that concentration of sulfur in plants depends largely on the amount of sulfur in the plant protein (Shirley, 1978).

Plant Microminerals

According to Underwood (1981), the iron concentration of herbage plants is a reflection of the species and the type of soil on which the plants grow. The majority of tropical soils are acid, a condition in which favors availability and plant uptake of iron, resulting in forage levels of this mineral generally in excess of requirements (McDowell, et al., 1984). McDowell (1985c) indicated that iron deficiency is considered rare for grazing cattle due to generally adequate pasture concentration along with contamination of plants by soils.

Manganese is essential for normal plant growth primarily because of its function in the enzyme systems

(Hewitt and Smith, 1975). Street and Rhue (1980a) reported that for most crops, manganese deficiency normally occurs when plant tissue concentration is less than 20 ppm, while toxicity occurs at levels in excess of 500 ppm for many plant species. Manganese deficiency in plants can be prevented by applying a manganese fertilizer to the soil and controlling the pH (Street and Rhue, 1980a). McDowell (1985a) indicated that the degree to which manganese deficiencies, excesses, or imbalances are practical problems for grazing livestock is not well defined.

In forage plants, the majority of copper salts in bound forms as water-soluble organic complexes (Underwood, 1977). Herbage species are known to differ in copper concentration; legumes, particularly, tend to be richer in copper than grasses (Gladstone et al., 1975). However, Forbes and Gelman (1981) reported that adjustment of botanical composition, with or without copper sulfate application, did not help to prevent hypocupremia in grazing livestock.

Underwood (1981) pointed out that since many forms of copper imbalance in grazing ruminants are brought about by interfering factors such as molybdenum, sulfur, calcium, zinc and iron, concentrations may also vary with soil characteristics, fertilizer usage and grazing system. It has been reported that a high organic matter content in soils is frequently associated with poor drainage and high water quantity which favors the uptake of molybdenum by plants (Beeson and Matrone, 1976). According to Reid and Horvath (1980), the levels of copper and molybdenum in forage plants are affected not only by soil properties but also by plant species, stage of growth and plant part. Although not all reports agree, concentrations of copper and molybdenum tend to decrease with advancing maturity, which is continuous in grasses but not in legumes (Fleming, 1973) Whitehead (1966) cited that normal concentrations of copper, molybdenum and sulfur in herbage species were 2 to 15 ppm, .1 to 4 ppm and .20 to .45%, respectively. However, Cunha (1973) stated that copper deficiencies usually occur when forage molybdenum exceeds 3 ppm and the copper level is less than 5 ppm. Furthermore, Lessard et al. (1970) indicated that sulfur values higher than .35% in forage were often associated with hypocupremia in animals. Molybdenosis occurred in grazing ruminants consuming high dietary molybdenum (20 to 100 ppm) with animals responding to copper supplementation (Reid and Horvath, 1980). In plants, molybdenum is known to be essential for the process of nitrogen fixation, and it must be present for nitrates to be metabolized into amino acids and proteins (Underwood, 1977, Brady, 1984).

Street and Rhue (1980b) indicated that zinc deficiencies have been verified as one of the most common occurring in agricultural crops. Underwood (1981) reported that zinc concentration in plants decreased with advancing maturity. Furthermore, legumes carry higher zinc concentrations than grasses grown and sampled under the same conditions. A zinc deficiency is considered when leaf tissue concentration is less than 20 ppm on a dry matter basis (Rhue and Street, 1980). The same author also indicated that the normal concentration range for zinc is between 25 to 150 ppm, while toxicity levels occur when leaf tissue concentration exceeds 450 ppm.

Cobalt is essential to the symbiotic fixation of nitrogen (Brady, 1984). Additionally, legumes and other plants are thought to have a cobalt requirement independent of nitrogen fixation, although the amount required is small compared to that for the nitrogen fixation process (Houser et al., 1978). Plants have varying degrees of affinity to cobalt, some being able to concentrate the element much more than others. Legumes generally have more ability to concentrate cobalt than grasses, and most of the cobalt present in plants tends to concentrate in the leaves (Houser et al., 1978). Houser et al. (1978) also suggested that less than .1 ppm cobalt in the forage should be considered cobalt deficient. However, the common levels for cobalt deficiency in forages which could affect ruminant status, reported by Latteur (1962), are as follows: .01 ppm, extremely deficient; .04 to .07, insufficient, .07, the lowest limit for health; and .1 to .3 ppm, adequate to increase productivity.

Selenium is closely related to sulfur and probably enters the plant by a similar mechanism to form the selenium-containing analogues of cysteine and methionine (Hewitt and Smith, 1975). Underwood (1977) stated that for all ordinary grasses and legumes, the primary determinant of selenium concentration is the level of available selenium in the soil. Waterlogging and rainfall are two factors contributing to selenium deficiency (Reuter, 1975). On the other hand, Ammerman et al. (1978) indicated that overliming can accentuate selenium toxicity for livestock in a seleniferous region. Acute selenium poisoning is most often associated with consumption of selenium-accumulator plants such as Astragalus racemosus, which may contain 100 to over 9,000 ppm selenium (McDowell, 1985b). In certain regions, accumulator plant species containing over 1000 ppm selenium are found growing alongside grasses containing less than 10 ppm (Beeson, 1961).

Mineral Status of Ruminants

Animal tissue-mineral concentrations may accurately portray the contribution of the total environment in meeting the mineral requirements of grazing animals, so they can be important indicators of mineral status (McDowell, 1985d).

Ideally, researchers would like to determine the mineral status of an animal by measuring the mineral concentration of one tissue which is readily available from a live animal (Conrad, 1978). Unfortunately, concentration of no single tissue will portray the status of all minerals. Since homeostatic control of mineral utilization is exercised in different ways for different elements, it is important to select organs or fluids for analysis which reflect the nutritional status of the animal (Reid and Horvath, 1980). An appropriate sampling approach of the substrates of greatest value in assessing and tracing mineral deficiencies recommended by Hartmans (1974), Conrad (1978) and Underwood (1981) is presented in table 1. McDowell (1985d) has also summarized the critical levels for diagnosis of specific mineral deficiencies or toxicities previously reviewed by McDowell (1976), NRC (1980), Mtimuni (1982) and McDowell et al. (1984).

Blood Minerals

Since blood can readily be drawn from live animals, a number of minerals have been determined in blood plasma or serum to indicate the status of the animals. One limitation to determining a mineral in blood has been its level of detection by instruments or methods used. However, according to NCMN (1973), blood is most relevant for detecting only zinc deficiency, while Conrad (1978)

TABLE 1. SUBSTRATES OF GREATEST VALUE IN ASSESSING AND TRACING MINERAL DEFICIENCIES

Mineral	Soil	Diet	Plasma	Liver	Bone	Saliva	Milk	Urine
Calcium		Ca	Ca		Ca			
Magnesium		Mg	Mg					Mg
Phosphorus		P	P		P			
Sodium		Na				Na (K)		Na
Chlorine		Cl						
Cobalt	Co	Co		Co				
Copper			Cu	Cu				
Iodine							I	I
Manganese		Mn		Mn				
Selenium		Se	Se	Se			Se	
Zinc		Zn	Zn			Zn		

Source: Hartmans (1974), Conrad (1978) and Underwood (1981).

suggested blood also for calcium, phosphorus, magnesium, copper and selenium.

Underwood (1981) considered calcium levels in blood plasma a good indicator of the calcium status of grazing animals and suggested 9-11 mg calcium per 100 ml blood plasma as the normal level. A deficiency results in lowered blood calcium values (Conrad, 1980). However, since physiological mechanisms (Guyton, 1966; Boris et al., 1978) control them effectively, only in extreme deficiency could blood calcium be low (NCMN, 1973). According to Cunha et al. (1964), values of 10-12 mg/100 ml in blood serum are normal for healthy cattle, and a deficiency occurs when these values fall below 8 mg/100 ml. Studies by Greene et al. (1983) demonstrated that calcium and phosphorus concentrations in serum and saliva are influenced not only by different supplies in the diet but also by the time of sampling.

Normal values for plasma inorganic phosphorus are 4-6 mg/100 ml for adults and a little higher, often 6-8 mg/100 ml, for very young animals (Underwood, 1981). However, NCMN (1973) did not consider serum inorganic phosphorus to be sufficiently sensitive to recommend it for diagnosis in cattle, because phosphorus in blood plasma varies widely and factors affecting this variation are not well understood. Little et al. (1971) reported that the rise in inorganic phosphorus of blood plasma, which occurs with time, is due to hydrolysis of organically combined phosphorus, such as adenosine triphosphate. Additionally, blood phosphorus could also increase in cattle with liver fluke infestation (Ogunrinade et al., 1980) and with some degree of stress (Gertner et al., 1965).

Generally, high dietary intake of magnesium increases blood serum magnesium (NRC, 1980). According to NCMN (1973), the magnesium status of animals is best assessed from magnesium levels in blood and urine. McDowell (1985d) suggested that serum magnesium levels of 1 to 2 mg/100 ml are considered deficient. However, Underwood (1981) considered 1.8 to 3.2 mg/100 ml serum magnesium as the normal range for cattle and a level less than 1 mg/100 ml indicates danger of tetany. Similarly, NCMN (1973) indicated that the approximate normal level of serum magnesium in cattle is 2 to 3.5 mg/100 ml. At a level of magnesium below 2 mg/100 ml, deficiency begins, with 1 mg/100 ml considered an extreme deficiency. Chicco et al. (1973) reported that high dietary calcium depressed magnesium content in bone and plasma.

The copper concentration is interchangeably reported in serum and plasma. However, copper in serum has been found to be higher (7%) than in plasma from the same blood sample (Owen, 1982). Although whole blood or plasma concentrations reflect the dietary copper status, the normal range is wide (Underwood, 1981). The same author indicated that the normal range for cattle may be .6 to 1.5 μg/ml, with a high proportion of values lying between .9 and 1.2 μg/ml. McDowell (1985d) listed the level of serum copper lower than .65 μg/ml as critical for cattle. Similarly, Underwood (1981) accepted that the whole blood or plasma copper values below .5 μg/ml are indicative of deficiency in cattle. However, Smith and Coup (1973) suggested this critical level could be too high. The copper status of blood can also be readily determined from serum ceruloplasmin activity, since ceruloplasmin (ferroxidase), synthesized in the liver, contains eight copper atoms per mole (Conrad, 1979).

Zinc concentration in serum or plasma is currently the most widely used criterion of zinc status. However, it is not sensitive to marginal zinc deficiencies (Apgar and Weich, 1982). Similarly, Conrad (1979) indicated that zinc levels in plasma and serum can only be markedly reduced by a severe zinc deficiency so that their practical diagnostic value is limited. According to NCMN (1973), zinc concentration in plasma of healthy cows is .6 to 1.4 μg/ml, thus indicating a normal zinc status. Mills et al. (1967) reported that 10 to 14 ppm of zinc in a semipurified diet were sufficient to maintain normal plasma levels between .9 and 1.2 μg/ml in calves.

The most widely used assessment of selenium status is blood selenium, since low levels are always found in selenium-deficient conditions. Hidiroglou (1980) found a direct relationship between blood gluthatione peroxidase activity and blood selenium concentration. However, Conrad (1978) suggested that kidney cortex and liver are the most sensitive indicators of selenium status so that selenium concentration in these organs can provide valuable diagnostic criteria. Thompson and Duncan (1982) reported that the activities of the enzyme glutathione peroxidase in whole blood and erythrocytes have also been used as a measure of selenium status in humans since the discovery of the association between selenium and glutathione peroxidase. The critical level of serum selenium listed by McDowell (1985d) is less than .03 µg/ml.

Liver Minerals

The liver is the central point of mineral metabolism in the animal body and is a useful organ for the estimation of iron and many other mineral statuses of animals (Boyazoglu et al., 1972). According to Underwood (1981), ferritin is the main iron storage compound and its concentration, along with hemosiderin, in tissues reflects the iron status of the animal. The normal values for iron in liver vary according to different researchers. Hartley et al. (1959) gave a range of 180 to 340 ppm, while Cunha et al. (1964) indicated values from 200 to 300 ppm, and Ammerman (1970) reported liver levels of 100 to 300 ppm iron in Florida cattle with adequate copper nutrition. Therefore, McDowell et al.

(1980) suggested values less than 180 ppm as the critical level. Differences in reported normal values of liver iron in cattle are due to the interrelationship of this element with other minerals. High dietary zinc, for example, is reported by Rosa et al. (1982) to reduce iron storage.

Since the liver is the main storage organ of body copper, liver copper concentrations would be expected to provide a useful index of the status of copper in the animal (Underwood, 1981). Liver copper concentrations reflect the dietary status, but they could be influenced by the dietary proportions of molybdenum and sulfur (Mills et al., 1976). On a dry weight basis, a wide range of values has been reported for the copper content of liver: 33 to 38 ppm (Bingley and Dufty, 1972), 70 ppm (Lindar and Munro, 1973), and 100 to 400 ppm (Underwood, 1981). However, it has been suggested that the approximate normal copper level in cattle is 200 ppm on a dry matter basis (NCMN, 1973; Underwood, 1977); levels below 50 ppm indicate a deficiency and below 10 ppm, severe deficiency (NCMN, 1973). McDowell (1985d) suggested 25 to 75 ppm are the critical levels.

Toxicosis is the main concern in molybdenum nutrition (McDowell et al., 1984). Langlands et al. (1981), studying changes in hepatic copper storage in sheep grazing pastures fertilized with sulfur and molybdenum, found that increased molybdenum fertilization reduced liver copper storage, while it was unlikely for copper deficiency to happen on molybdenum application at commercial rates. Suttle (1980) reported that less than 10 ppm dietary molybdenum in ruminants could affect copper metabolism. McDowell (1985d) suggested the level of molybdenum above 4 ppm as indicative of an excess of this element.

Underwood (1977) suggested that liver zinc values above 125 ppm should be considered as the normal value for cattle. Meanwhile, values from 84 to 132 ppm in cattle liver were considered normal by Miller and Miller (1962). Factors which reduce zinc absorption in the gastro-intestinal tract, such as phytic acid, calcium, magnesium, phosphorus, copper and chelating agents such as EDTA, have also been found to reduce zinc concentration in the liver (Miller, 1975). Therefore, many researchers argue that liver zinc is a good indicator for zinc status (Watson et al., 1973).

Although there is as yet no practical criterion for assessing the manganese status of animals, liver manganese concentration seems the most promising (NCMN, 1973). The normal level of liver manganese in cattle was reported to be 8 to 10 ppm (Underwood, 1977). Egan (1975) considered liver manganese values below 6 ppm as indicating deficiency. McDowell et al. (1978) concluded that manganese deficiency can best be detected when there is a combination of less than 6 ppm of manganese in the liver and less than 20 to 40 in the diet. In general, the value of 8 ppm manganese in liver is accepted as the critical level (McDowell, 1985d).

Cobalt concentration in cattle liver is sufficiently responsive to changes in cobalt intake to have some value in the diagnosis of cobalt deficiency (Conrad, 1978; Underwood, 1981). Ammerman (1981) reported that a decrease in ruminant liver cobalt storage and vitamin B_{12} are indicative of a dietary cobalt deficiency. Therefore, McDowell (1985d) suggested that liver cobalt levels between .05 to .07 ppm are deficient, while levels above that are normal for healthy animals. However, Conrad (1978) reported that most studies indicated that values of less than .1 ppm liver cobalt could be considered deficient.

As previously stated, Conrad (1978) indicated that the most sensitive indicators of the selenium status are kidney cortex and liver. Furthermore, the author suggested that concentrations greater than 1 ppm selenium in the kidney and .1 ppm in the liver are considered normal. McDowell (1985d) listed .25 ppm as the critical level.

Bone Minerals

Since there is little variation in the elementary composition of bone ash, and calcium and phosphorus usually occur in a ratio of approximately 2:1 (Maynard et al., 1979), many researchers suggest that bone provides a more reliable value for assessing calcium and phosphorus statuses than blood (Cohen, 1973). The nature of the diet can affect somewhat the mineral relationship in bone, even though the ash content is not appreciably changed (Maynard et al., 1979). Furthermore, the same author stated that in mammals, bone is made of approximately 36% calcium, 17% phosphorus and .8% magnesium, based on dry, fat free analysis. A similar bone composition was also reported by Ammerman et al. (1974) for grazing cattle as 37.6 to 38.2% calcium and 17.6 to 18.1% phosphorus in bone ash. Little (1972) suggested that calcium or phosphorus concentration per unit volume has greater sensitivity than per unit fresh weight, moisture-free and fat-free basis, since in the last two, water and fat contents were not taken into account. It has been suggested that values of 120 mg phosphorus per ml bone from the 12th rib indicate deficiency, and that levels of bone phosphorus greater than 150 mg/ml indicate adequacy (Little and Shaw, 1979).

Normal magnesium conrentrations in rib bone of cattle range from 67 to .7% (Blaxter and Sherman, 1955). Values reported by Lebdosoekojo et al. (1980) for grazing young bulls were .60 to .73% in rib bone ash. Underwood (1981) reported that there was no gross fall in skeletal magnesium of animals suffering from hypomagnesia with tetany that arises suddenly.

CHAPTER III
MATERIALS AND METHODS

Description of Research

Soil, forage and animal tissue samples were collected from different administrative districts within a climatic region in the province of South Sulawesi, Indonesia during both the rainy and dry seasons. Collections were made at three, three and four districts in the Western, Central and Eastern regions, respectively, for each season. Those districts were Jeneponto, Gowa and Barru in the Western region; Polmas, Enrekang and Sidrap in the Central region; and Wajo, Soppeng, Bone and Bulukumba in the Eastern region. The regions were selected based on the rainfall pattern classified by Schmidt and Ferguson (1951) and Oldeman and Darmiyati (1977). The majority areas within the Western region has the rainfall type C and D (3 to 6 wet and <2 to >5 dry months), the Central region has the rainfall type A and B (7 to >9 wet and 2 to 4 dry months); and the Eastern region has the reinfall type B and C (5 to 9 wet and <2 to 5 dry months).

The sampling periods were February-March and August-September of 1987 The February-March sampling period corresponded to the end of rainy season in the Western and Central regions, and to the end of dry season in the Eastern region. On the other hand, the August-September sampling period corresponded to the end of dry season in the Western and Central regions, and to the end of rainy season in the Eastern region. In the Central region, however, there was no marked differences between the rainy and dry seasons.

Blood, bone and liver samples were collected from the slaughtered animals at slaughterhouses in the municipality of Ujung Pandang and Pare Pare, and in the district of Gowa, Polmas, Enrekang, Soppeng and Bone. Animals were identified for their district of origin based on the animals' ownership or identification card recorded and kept by the official at slaughterhouses. Samples were taken from the first 15 to 25 animals slaughtered for each district. From all districts selected, the animals sampled were male Bali cattle that were three to four years old and weighed from 250 to 300 kg. Additionally, tissue samples were also obtained from male water buffaloes that originated from the districts of Gowa, Polmas, Enrekang and Bone. The buffaloes were the water or swamp breed commonly found throughout Southeast Asia that were three to four years old and weighed in the range of 300 to 350 kg. The age of animals recorded in the identification card was confirmed by the presence of three pairs of incisor teeth for three to four years old-animals (Habel and St. Clair, 1975).

During each period of sample collection, animals which had been sampled for each district were traced back to the original owners. If determined that the animal had been owned for less than six months or the owner has a stall-feeder, with the possibility that the animal had been stall-fed, the obtained tissue samples were excluded from the study. Otherwise, the owners were asked about pastures or grazing areas where the animals were grazed. Forage samples were then collected after carefully observing the grazing pattern of animals present at the time of collections. Soil samples were taken from the same site of the pasture where forage samples had been taken.

Sample Collection

Soil Samples

Three composite soil samples from grazing areas in each district were collected. Each of the three composite soil samples for each district came from 10 to 20 samples. Soils were sampled according to the technique described by Sahia (1978). The depth of the soil sampled was about 20 cm, similar to the length of the majority of the forage root systems. Soil samples were then air-dried and crushed in a stainless steel sieve with a hard rubber ring. A subsample of approximately 500 g was finally taken for analyses.

A total of 9, 9 and 12 soil samples were collected from the Western, Central and Eastern regions, respectively, for each season. Although soil samples collected in each district during the rainy and dry seasons did not come from the same spot, they came from the same grazing areas.

Forage Samples

Six composite forage samples of the major species in grazing areas were taken in each district. Each of the composite forage samples came from 10 to 20 individual samples of the same forage species. The forage species sampled were as follows: *Cynodon dactylon*, *Paspalum conjugatum*, *Axonopus compressus*, *Drymaria cordata*, *Panicum* sp., *Stenotaphrum secundatum*, *Digitaria sanguinalis*, *Themeda* sp., *Imperata cylindrica*, *Euphorbia hirta*, *Panicum repens*, *Andropogon aciculatus*, *Sporobulus bacteriganus*, *Leucaena leucocephala*, *Eleusine indica* and *Themeda arguens*.

To avoid contamination, plastic gloves and stainless steel scissors were used for sample collection. In addition, only the aerial part of the forage was clipped. Samples were collected in a cloth bag for immediate air-drying. Later, forage samples were dried at 65°C in a drying oven and then ground in a hammer mill with stainless steel knives to pass through a 1-mm screen. After mixing, a 100-g subsample was taken for analysis.

A total of 18, 18 and 24 forage samples were collected from the Western, Central and Eastern regions, respectively, for each season. Forage samples collected in each district for the two sampling periods did not come from the same spot but came from the same grazing areas.

Animal Tissue Samples

Blood, liver and bone samples were collected from slaughtered animals at the slaughterhouse. After tracing ownership of the animals that were sampled, tissue samples from 10 cattle for each district were included in this study. A total of 30, 30 and 40 tissue (blood, liver and bone) samples were obtained from the Western, Central and Eastern regions, respectively, for each season. In addition, tissue samples from water buffaloes were also obtained from the district of Gowa, Polmas, Enrekang and Bone. The number of buffalo tissue samples collected from each district during the rainy and dry seasons, respectively were as follows: Gowa, 15 and 19; Polmas, 12 and 17; Enrekang, 12 and 15; Bone, 19 and 23.

Blood. When the animals were killed by exsanguination, duplicate blood samples were collected into silicon-coated glass tubes with and without heparin. The tube had a zinc-free rubber stopper. Blood samples were immediately placed on ice and centrifuged in less than 24 hours to obtain plasma and serum samples. These plasma and serum samples were stored frozen until further preparation and analysis.

Liver. Liver samples were taken immediately after the abdomen was opened. To avoid contamination, plastic gloves and a stainless steel knife were used. A small area of the lobus dexter was scrapped, then approximately 50 g of liver was taken, placed into a plastic bag and put on ice immediately. Liver samples were stored frozen for further preparation and analysis.

Bone. Bone samples were taken before the carcass was washed. A section of the 12th rib bone from the right side, about 5 cm in length, was removed using a stainless steel saw. Muscle was scraped off the bone before putting the sample into a plastic bag and keeping it on ice. Later, bone samples were stored frozen until further preparation and analysis.

Chemical Analysis

Soil Samples

Soil samples were analyzed according to procedures used by the IFAS Extension Soil Laboratory at the University of Florida (Rhue and Kidder, 1983). Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium, phosphorus, copper, iron, manganese and zinc. Minerals were extracted from soil using

Mechlich I extracting solution method (.05 N HCL + .025 N H_2SO_4). Soil mineral concentrations were then determined by inductively coupled argon plasma in a Thermo Jarrel-Ash ICAP, Model 9000 (Jarrel-Ash Division, 1982).

Forage Samples

Forage samples were prepared and analyzed for mineral concentration according to methods described by Fick et al. (1979). Calcium, potassium, magnesium, sodium, copper, iron, manganese and zinc were analyzed by atomic absorption spectrophotometry using a Perkin-Elmer AAS, Model 5000 with AS-50 autosampler (Perkin-Elmer Corp., 1982). Cobalt and molybdenum were determined by flameless atomic absorption spectrophotometry on a Perkin-Elmer Zeeman/3030 AAS equipped with HGA 600 graphite furnace and Zeeman-effect background corrector (Perkin-Elmer Corp., 1984). Phosphorus was determined by the colorimetric method of Harris and Popat (1954) included by Fick et al. (1979) as a method for phosphorus determination in plant and animal tissue. Selenium was analyzed using a modification of the fluorometric method described by Whetter and Ullrey (1978). Additionally, crude protein concentrations in forages were determined by measuring total nitrogen on a Technicon Autoanalyzer II, following the method described by Gallaher et al. (1975) and Technicon Industrial Systems (1978).

Animal Tissue Samples

Blood plasma and serum. Blood plasma and serum were deproteinized with 10% trichloroacetic acid (TCA) and then analyzed for mineral concentration according to the method described by Fick et al. (1979). Plasma samples were analyzed for calcium and phosphorus, while serum was analyzed for magnesium, copper, zinc and selenium. Calcium, magnesium, copper and zinc were analyzed by atomic absorption spectrophotometry using a Perkin-Elmer AAS, Model 5000 with AS-50 autosampler (Perkin-Elmer Corp., 1982). Phosphorus was determined using the colorimetric method (Harris and Popat, 1954) and selenium was analyzed using the modified fluorometric method of Whetter and Ullrey (1978).

Liver. Preparation of the liver samples was carried out as described by Fick et al. (1979). The solutions were then analyzed for copper, iron, manganese and zinc by atomic absorption spectrophotometry using a Perkin-Elmer AAS, Model 5000 with AS-50 autosampler (Perkin-Elmer Corp., 1982). Liver cobalt and molybdenum were determined by flameless atomic absorption spectrophotometry on a Perkin-Elmer Zeeman/3030 AAS equipped with HGA 600 graphite furnace and Zeeman-effect background corrector (Perkin-Elmer Corp., 1984). Selenium determination was carried out by the modified fluorometric technique of Whetter and Ullrey (1978).

Bone. Specific gravity, expressed in g/cm^3, was measured from air-dried bone samples using a Mettler ME-40290 kit (Mettler Instruments AG, CH-8606 Greifensee, Switzerland). The samples were subsequently prepared according to the procedure of Fick et al. (1979) to obtain fat-free bone ash for calcium, magnesium and phosphorus analyses using the same equipments as previously described for the same elements in forage and blood samples.

Statistical Analysis

Data obtained in this study were analyzed statistically using a mixed model (Snedecor and Cochran, 1980) with the General Linear Models (GLM) procedure of the SAS System (SAS Institute Inc., 1987). Although forage samples were collected separately by species, the species could not be included in the mathematical model. Uneven occurrences of many of the sampled forage species produced a large number of empty cells. Therefore, the same model was used for soil, forage and cattle tissue (blood, bone and liver) data from the ten districts included in this study. The model was as follows:

$$Y_{ijkl} = \mu + S_i + R_j + SR_{ij} + D_{k(j)} + SD_{ik(j)} + e_{ijkl}$$

where,

μ = Overall mean;

S_i = Fixed effect of ith season;

R_j = Fixed effect of j^{th} region;

SR_{ij} = Fixed interaction effect of j^{th} region and i^{th} season;

$D_{k(j)}$ = Random effect of k^{th} district within j^{th} region;

$SD_{i(k(j))}$ = Random interaction effect of k^{th} district within j^{th} region and i^{th} season;

ε_{ijkl} = Random component of error.

From the expected mean squares under this model, season and season by region interaction effects were tested using mean squares of the season by district within region interaction as the error term. The region effect was tested using the district within region mean squares as the error term. Variance components of the random effects were calculated using coefficients of expected mean squares from the output of the RANDOM statement in the GLM procedure. Orthogonal contrasts were performed for the Central vs Western and Eastern regions, and for the Western vs Eastern regions. Due to unequal subclass numbers, least squares means were calculated using the same error term as described above. In addition, gross and partial correlation coefficients were estimated for variables in the soil, forage, blood, bone and liver; and between forage and soil, blood and forage, bone and forage, liver and forage, blood and bone, and blood and liver variables. Gross correlation coefficients were estimated using the CORR procedure, while partial correlation coefficients were estimated using the MANOVA statement in the GLM procedures of the SAS System (SAS Institute Inc., 1987).

As previously mentioned, in both the rainy and dry seasons, blood, bone and liver samples of water buffaloes were also obtained from four of the ten districts included in this study. Data from these samples were compared to the corresponding cattle tissue data from the same district and season. Statistical analyses were performed using the following model:

$$Y_{ijkl} = \mu + S_i + D_j + SD_{ij} + A_k + SA_{ik} + DA_{kj} + SDA_{ijk} + e_{ijkl}$$

where,

μ = Overall mean;

S_i = Fixed effect of ith season;

D_j = Random effect of jth district;

SD_{ij} = Random interaction effect of jth district and ith season;

A_k = Fixed effect of kth animal species;

SA_{ik} = Fixed interaction effect of kth animal species and ith season;

DA_{kj} = Random interaction effect of kth animal species and jth district;

SDA_{ijk} = Random interaction effect of kth animal species and jth district and ith season;

e_{ijkl} = Random component of error.

From the expected mean squares under this model, the season effect was tested using mean squares of the season by district interaction as the error term, and the animal species effect was tested using mean squares of the district by animal species interaction as the error term. The season by animal species interaction effect was tested using mean squares of the season by district by animal species interaction as the error term. Variance components of the random effects were calculated using coefficients of expected mean squares from the output of the RANDOM statement in the GLM procedures. Least squares means were calculated using the same error term as described above. In addition, statistical analyses also were performed for soil and forage data from those four districts using the following model:

$$Y_{ijk} = \mu + S_i + D_j + SD_{ij} + e_{ijk}$$

where,

μ = Overall mean;

S_i = Fixed effect of i^{th} season;

D_j = Random effect of j^{th} district;

SD_{ij} = Random interaction effect of j^{th} district and i^{th} season;

e_{ijk} = Random component of error.

The season effect was tested using mean squares of the season by district interaction as the error term.

The word "critical" is used in this paper to denote concentrations below which are considered deficient or, in some cases, above which are excessive quantities associated with specific clinical signs. For forages, the levels are based on the estimated mineral requirements of beef cattle (NRC, 1984). However, it should be borne in mind that the total quantity consumed per day, not the concentration in forage, determines the true adequacy of a nutrient.

CHAPTER IV
MINERAL STATUS OF GRAZING CATTLE IN SOUTH SULAWESI, INDONESIA: I. MACROMINERALS

Introduction

For grazing ruminants, forages are the major sources of the essential nutrients. Only rarely, however, can tropical forages completely satisfy all nutrient requirements, especially minerals (McDowell, 1985a). In tropical countries, nutritional mineral imbalances are frequently a major limitation to ruminant livestock production Most naturally occurring mineral deficiencies are associated with specific regions and are directly related to climatic and soil characteristics (McDowell et al., 1980)

Although more attention is being paid to mineral nutrition of Indonesian livestock, in South Sulawesi only a few studies on mineral status and supplementation have been conducted. Even fewer have been reported in the available literature.

The purpose of this study was to evaluate the mineral status of grazing cattle in three climatic regions of South Sulawesi, Indonesia. In the present chapter the status of macrominerals and crude protein is determined.

Experimental Procedure

Soil, forage and animal tissue samples were collected from ten different districts within three climatic regions in South Sulawesi, Indonesia during the rainy and dry seasons. For each season, collections were made at three, three and four districts within the Western, Central and Eastern regions, respectively. Sampling periods were February-March and August-September of 1987, corresponded to the end of rainy and dry seasons in each region.

Samples of 30 soils, 60 forages and 100 blood and rib bone samples from slaughtered animals were obtained for each of the sampling periods. The animals sampled were male Bali cattle, that were three to four years old and weighed in the range of 250 to 300 kg; slaughtered at slaughterhouses in the various districts. Animals which had been sampled were traced back to the original owners in each district where samples of soil and forage were collected from the grazed pastures.

Soils were sampled according to the technique described by Bahia (1978), with samples analyzed according to the procedures used by the IFAS extension soil testing laboratory at the university of Florida, Gainesville (Rhue and Kidder, 1983). Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium and phosphorus. Minerals were extracted from soils using the Mehlich I extracting solution method (.05 N HCl + .025 N H_2SO_4). Forage samples were processed according to methods described by Fick et al. (1979) and were analyzed for calcium, potassium, magnesium and sodium. Blood plasma samples were analyzed for calcium and phosphorus, while serum was analyzed for magnesium. Bones were prepared according to the procedure of Fick et al. (1979) to obtain fat-free bone ash for calcium, magnesium and phosphorus analyses.

Calcium, potassium, magnesium and sodium were determined by atomic absorption spectrophotometry (Perkin-Elmer Corp., 1982). Phosphorus was analyzed using the colorimetric method of Harris and Popat (1954). Additionally, bone specific gravity was measured using a Mettler ME-40290 kit (Mettler Instruments AG, CH-8606 Greifensee, Switzerland), expressed in g/cm^3; and forage crude protein concentrations were determined by measuring total nitrogen following the method described by Gallaher et al. (1975) and the Technicon Industrial Systems (1978).

Data obtained in this study were analyzed statistically using a mixed model (Snedecor and Cochran, 1980) with the General Linear Models (GLM) procedure of the SAS System (SAS Institute Inc., 1987). Gross and partial correlation coefficients were estimated for minerals in the soil, forage, blood and bone; and between forage and soil, blood and forage, bone and forage, and blood and bone minerals.

Results and Discussion

Soil Analyses

Results of soil analyses as related to season and region are presented in table 2 and the percentages of soil samples deficient in macrominerals, compared to the critical values recommended for Florida soils (Breland, 1976; Rhue and Kidder, 1983) are shown in table 3. Seasonal differences were found for soil organic matter ($P<.01$), soluble salts ($P<.01$), calcium ($P<.01$), potassium ($P<.05$) and sodium ($P<.01$) concentrations. The concentrations in the rainy season were higher for soluble salts, calcium, potassium and sodium, but lower for organic matter; in comparison to those in the dry season. The concentrations of organic matter and soluble salts also were affected ($P<.01$) by the season and region interaction.

Regional differences ($P<.10$) were found for soil organic matter concentrations. The Central region had higher ($P<.10$) soil organic matter concentrations than the other two regions.

Soil pH was similar ($P>.10$) for all regions during both the rainy and dry seasons. Aluminum ion is reported to be the dominant cation associated with soil acidity below pH 5.5 (Sanchez, 1976). Although soil extractable aluminum was found to be relatively high, soil pH was above 5.5 for each of the regions in both seasons. Therefore, it appeared that

TABLE 2. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MACROMINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	Significance[c]
OM[d], %	Rainy	4.3	.14	5.7	.14	4.2	.12	S^{**},R^{*},SR^{**},C_1^{*}
	Dry	6.3	.14	7.4	.14	4.7	.12	
pH	Rainy	5.6	.28	5.8	.28	6.0	.24	
	Dry	6.3	.28	5.8	.28	6.0	.24	
SS[e], ppm	Rainy	427	16	678	16	628	13	S^{**},SR^{**}
	Dry	357	16	472	16	429	13	
Al, ppm	Rainy	1211	27	1197	27	1172	23	
	Dry	1191	27	1241	27	1153	23	
Ca, ppm	Rainy	983	21	952	21	1058	18	S^{**},$D(R)^{**}$
	Dry	586	21	556	21	656	18	
K, ppm	Rainy	306	10	133	10	189	9	S^{*},R^{*},$D(R)^{**}$, C_1,C_2
	Dry	291	10	109	10	154	9	
Mg, ppm	Rainy	235	46	338	46	348	40	$D(R)^{**}$,$SD(R)^{**}$, C_2^{*}
	Dry	240	46	319	46	410	40	
Na, ppm	Rainy	40.4	4.8	25.7	4.8	45.1	4.1	S^{**},R^{*},$D(R)^{*}$, $SD(R)^{*}$,C_1^{*}
	Dry	23.3	4.8	18.2	4.8	28.1	4.1	

TABLE 2. CONTINUED

		Region						
		Western		Central		Eastern		
Variable	Season	Mean	S.E.	Mean	S.E.	Mean	S.E.	Significance
P, ppm	Rainy	9.9	.36	18.8	.36	19.8	.31	$R^{**}, C_1^{+}, C_2^{**}$
	Dry	9.3	.36	18.3	.36	19.3	.31	

[a] Least squares means of 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern

[d] Organic matter.

[e] Soluble salts.

$^{**}P<.01$.

$^{*}P<.05$.

$^{+}P<.10$

TABLE 3. PERCENTAGE OF SOIL SAMPLES DEFICIENT IN MACROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Ca, ppm	< 71	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
K, ppm	< 62	Rainy	0.0	0.0	16.7	6.7
		Dry	0.0	11.1	8.3	6.7
Mg, ppm	< 30	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
P, ppm	< 17	Rainy	100.0	44.4	41.7	60.0
		Dry	100.0	44.4	50.0	63.3

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[a] Percentages based on 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient, based on recommendations for Florida soils (Breland, 1976; Rhue and Kidder, 1983).

this high concentration of aluminum did not have much effect on the reduction of available soil phosphorus and the consequent uptake by plants as indicated by Sanchez (1976).

Regional differences (P<.01) were found for soil phosphorus concentrations. Furthermore, among the macroelements analyzed, phosphorus was deficient (< 17 ppm) most often, with 100, 44 and 42% of samples deficient during the rainy season for the Western, Central and Eastern regions, respectively. Similar percentages of deficient samples were found for each region during the dry season. Lower (P<.01) soil phosphorus concentrations were found in the Western region in comparison to those in the Eastern region. Tropical soils are generally reported to be deficient in phosphorus (Volkweiss, 1978).

Regional differences (P<.05) also were found for soil potassium and sodium. However, the average concentration for potassium in each of the regions during both seasons was above the critical value for deficiency (62 ppm) recommended by Rhue and Kidder (1983) for Florida soils. Similar information was reported by Popenoe (1960) for the humid tropical climate in Central and South American countries where clearing and burning of plant material would deposit large amounts of exchangeable potassium in the topsoil.

Among other soil macroelements, no deficiencies were detected for the different regions and seasons, although variations due to the district effect (P<.05) were observed for calcium, potassium, magnesium and sodium concentrations. The season by district interaction effect (P<.05) was found for potassium and sodium concentrations.

Forage Analyses

Forage macromineral and crude protein concentrations for the rainy and dry seasons in the three regions are shown in table 4. The percentages of deficient forage samples, based on the suggested critical values for minerals (McDowell, 1985d) and crude protein (Milford and Minson, 1966) are presented in table 5.

Forage calcium concentrations were similar (P>.10) for all regions during both the rainy and dry seasons. Although calcium concentrations varied due to the district and the interaction of season and district effects, the average concentration for each of the regions in both seasons was above the value regarded as critical for deficiency (.3%) suggested by McDowell (1985d).

Regional differences (P<.05) were detected for forage potassium. Forage potassium concentrations were lower (P<.10) in the Central than the other two regions, while those for the Eastern region were lower (P<.10) compared to the Western region. Since potassium in plants is associated with young growing tissue, it is not surprising that potassium is not a problem when plants are still in the active stage of growth (Gomide, 1978). Individual

TABLE 4. FORAGE MACROMINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND REGION

Variable	Season	Region						Significance^{c}
		Western		Central		Eastern		
		Mean^{a}	S.E.^{b}	Mean	S.E.	Mean	S.E.	
Ca, %	Rainy	.44	.08	.39	.08	.35	.07	D(R)**, SD(R)**
	Dry	.36	.08	.35	.08	.48	.07	
K, %	Rainy	2.40	.21	1.53	.21	1.78	.18	R*, D(R)**, SD(R)*
	Dry	2.12	.21	1.24	.21	1.49	.18	C_1^{*}, C_2^{*}
Mg, %	Rainy	.21	.02	.23	.02	.32	.01	SR*, D(R)**, C_2^{+}
	Dry	.21	.02	.27	.02	.26	.01	
Na, %	Rainy	.13	.02	.07	.02	.08	.02	R*, D(R)*, SD(R)**
	Dry	.09	.02	.04	.02	.07	.02	C_1^{*}, C_2^{*}
P, %	Rainy	.18	.03	.27	.03	.26	.02	R*, D(R)**, SD(R)$^{+}$
	Dry	.17	.03	.28	.03	.25	.02	C_2^{+}

TABLE 4. CONTINUED

		Region						
		Western		Central		Eastern		
Variable	Season	Mean	S.E.	Mean	S.E.	Mean	S.E.	Significance
CP[d], %	Rainy	8.7	.49	9.2	.49	9.1	.43	S[*],D(R)[*]
	Dry	7.6	.49	7.7	.49	7.7	.43	

[a] Least squares means of 6 samples/district (3 samples/district for CP) with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

[d] Crude protein.

[**] $P<.01$.

[*] $P<.05$.

[+] $P<.10$.

TABLE 5. PERCENTAGE OF FORAGE SAMPLES DEFICIENT IN MACROMINERALS AND CRUDE PROTEIN[a]

Variable	Critical level[b]	Season	Region Western	 Central	 Eastern	Overall
Ca, %	< .3	Rainy	27.8	33.3	16.7	25.0
		Dry	38.9	33.3	25.0	31.7
K, %	< .8	Rainy	0.0	5.6	16.7	8.3
		Dry	0.0	0.0	12.5	5.0
Mg, %	< .2	Rainy	44.4	33.3	16.7	30.0
		Dry	33.3	0.0	25.0	20.0
Na, %	< .06	Rainy	33.3	50.0	41.7	41.7
		Dry	0.0	77.8	45.8	41.7
P, %	< .25	Rainy	88.9	55.6	54.2	65.0
		Dry	88.9	33.3	45.8	55.0
Crude protein, %	< 7	Rainy	11.1	0.0	16.7	10.0
		Dry	33.3	22.2	33.3	30.0

[a] Percentages based on 6 samples/district (3 samples/district for crude protein) with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient (Milford and Minson, 1966; McDowell, 1985d), based on requirements of beef cattle (NRC, 1984).

evaluation of samples based on the critical potassium level of .8% (McDowell, 1985d) indicated that only small percentages of them were deficient. The region with highest percentage of samples below the critical concentration in both seasons was the Eastern region.

Season by region interaction effects ($P<.05$) were found for forage magnesium concentrations. Magnesium in forages from the Western region was lower ($P<.10$) than in those from the Eastern region. The percentage of samples found below the critical concentration of .2% (McDowell, 1985d) for the Western region was the highest among regions. Reid and Horvath (1980) indicated the effect of acid, highly leached soils and potassium fertilization on the impaired absorption and reduced availability of magnesium to the plant. Therefore, an explanation for the higher percentage of samples deficient in magnesium in the Western region could be due to soils with relatively high amounts of potassium as was also found in the same region.

Sodium concentrations in forages varied ($P<.10$) among the three regions. The Central region had lower ($P<.05$) concentrations than the other two regions, and the Eastern region had lower ($P<.10$) concentrations than the Western region. Individual evaluation of samples below the critical level of .06% (McDowell, 1985d) also indicated that forage samples from the Central region had the highest percentage of sodium deficiency in both seasons. The overall percentage of forage samples deficient in sodium in both the rainy and dry seasons was 42%.

Regional differences (P<.10) were found for forage phosphorus concentrations, with the Western region having lower (P<.10) concentrations than the Eastern region. Of all samples analyzed, 65% were deficient in phosphorus (<.25%) during the rainy season and 55% were deficient during the dry season. In the Western region, 83% of forage samples analyzed were deficient in phosphorus in both seasons. Forage phosphorus concentrations also varied due to district (P<.01) and the interaction of season and district (P<.10) effects.

Crude protein was the only variable analyzed in forages showed seasonal differences (P<.05). The concentrations in the rainy season were higher than those in the dry season. For either season, however, crude protein concentrations were not different (P>.10) among regions. The overall percentage of forage samples below the crude protein value of 7%, regarded as critical for protein deficiency (Milford and Minson, 1966) was higher in the dry season than in the rainy season (30 vs 10%). This is in agreement with Gomide (1978) who found decreased forage nitrogen, phosphorus and potassium with increasing forage maturity. Moore (1980) suggested that mature forages having less than 7 to 8% crude protein are likely to show increased intake due to protein supplementation. Therefore, supplemental protein during the dry season may also be suggested for grazing cattle in South Sulawesi, that may increase voluntary forage intake, energy digestibility and animal performance.

Animal Tissue Analyses

Blood. Blood macromineral concentrations as related to season and region are presented in table 6, with percentages of deficient blood samples shown in table 7. There were no seasonal and regional effects ($P>.10$) in plasma calcium concentrations, but variations ($P<.01$) due to the district and the interaction of season by district effects were found. However, the average calcium concentration for all regions were greater than the critical level of 8 mg/dl suggested by McDowell (1985d). The incidence of calcium deficiency as the percentage of samples below critical levels for the Western, Central and Eastern regions, respectively, during the rainy season was 17, 13 and 5, and the overall incidence was 11%. Similarly, for the dry season, the percentages were 10, 7 and 13% for the Western, Central and Eastern regions, respectively, and the overall incidence of deficiency was 10%.

Seasonal differences ($P<.05$) were found for serum magnesium with concentrations during the dry season higher than those in the rainy season. A season by region interaction effect ($P<.10$) also was observed for serum magnesium. Serum magnesium concentrations for the Central

TABLE 6. BLOOD MACROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable[a]	Season	Mean[b]	S.E.[c]	Mean	S.E.	Mean	S.E.	Significance[d]
Ca, mg/dl	Rainy	8.4	.14	8.5	.14	8.5	.12	$D(R)^{**}$, $SD(R)^{**}$
	Dry	8.5	.14	8.7	.14	8.5	.12	
Mg, mg/dl	Rainy	2.2	.10	2.2	.10	2.5	.09	S^{*}, R^{+}, SR^{+}, $D(R)^{*}$,
	Dry	2.7	.10	2.4	.10	2.5	.09	$SD(R)^{**}$, C_1^{+}
P, mg/dl	Rainy	8.2	.81	6.1	.81	5.2	.70	$D(R)^{**}$, $SD(R)^{**}$,
	Dry	8.4	.81	5.2	.81	5.1	.70	C_2^{*}

[a] Plasma for Ca and P, and serum for Mg.

[b] Least squares means of 10 samples/district with 3, 3 and 4 districts within Western Central and Eastern regions, respectively, for each of the seasons.

[c] Standard error of least squares means.

[d] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

** $P<.01$.

* $P<.05$.

+ $P<.10$.

TABLE 7. PERCENTAGE OF BLOOD PLASMA AND SERUM SAMPLES DEFICIENT IN MACROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Plasma Ca, mg/dl	< 8	Rainy	16.7	13.3	5.0	11.0
		Dry	10.0	6.7	12.5	10.0
Serum Mg, mg/dl	< 2	Rainy	20.0	20.0	2.5	13.0
		Dry	0.0	0.0	5.0	2.0
Plasma P, mg/dl	< 4.5	Rainy	16.7	0.0	30.0	17.0
		Dry	6.7	26.7	32.5	23.0

[a] Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient (McDowell, 1985d).

region were lower (P<.10) than the other two regions. In the rainy season, a higher incidence of magnesium deficiency was found in the Western and Central regions than in the Eastern, with 20% of samples for both regions below the critical concentration of 2.0 mg/dl suggested by McDowell (1985d). It is important to mention that these two regions also had higher percentage of low forage magnesium concentrations during the rainy season. During the dry season, the overall incidence of low serum magnesium decreased to 2%. McDowell et al. (1984), in a review of the diagnosis of specific mineral deficiencies and toxicities in cattle, reported that blood magnesium levels of 1 to 2 mg/dl are considered deficient, and a level of less than 1 mg/dl indicates danger of tetany.

Plasma phosphorus is not recommended as a practical criterion for assessing phosphorus status of grazing animals (NCMN, 1973). There are many factors which could affect plasma phosphorus. Plasma phosphorus concentration is not nearly as constant as calcium level; this is understandable since blood phosphorus is in equilibrium, not only with bone phosphorus, but also with that arising from a large number of organic phosphorus compounds produced as a result of cellular metabolism (Irving, 1973). However, if the methods of collection and sample preparation are controlled, it is considered a good indication of status. Therefore, blood phosphorus values continue to be reported in the literature.

No seasonal or regional differences (P>.10) were found for plasma phosphorus, although variations (P<.01) due to the district and the interaction of season by district effects were observed. During the rainy season, the Eastern region showed the highest percentage (30%) of samples below the critical concentration of 4.5 mg/dl suggested by McDowell (1985d), followed by the Western region (17%) and none was detected for the Central region. The overall percentage of deficiency was 17. In the dry season, the overall percentage of deficient samples was 23. Compared to the rainy season, a higher incidence of deficiency was found in the Central region while a lower incidence was found in the Western region.

Bone. Bone macromineral concentrations and specific gravity as related to season and region are presented in table 8, with the percentages of deficient bone samples shown in table 9. There were no differences (P>.10) for seasons and regions in any of the bone variables analyzed, with the exception of specific gravity that exhibited regional differences (P<.01). The values for bone specific gravity in the Central region were higher (P<.01) than the other two regions. However, the percentage of deficiencies based on the suggested critical levels (Little, 1972; McDowell, 1985d) for all minerals analyzed in each season and region was high.

TABLE 8. BONE MACROMINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	Significance[c]
Ca, %	Rainy	22.6	.37	22.8	.37	23.1	.32	SD(R)$^{+}$
	Dry	23.2	.37	23.3	.37	23.0	.32	
Mg, %	Rainy	.49	.04	.47	.04	.43	.03	SD(R)**
	Dry	.41	.04	.42	.04	.46	.03	
P, %	Rainy	10.1	.24	10.2	.24	10.1	.21	SD(R)*
	Dry	10.1	.24	10.2	.24	10.2	.21	
Ash, %	Rainy	62.2	1.24	62.1	1.24	63.3	1.07	SD(R)**
	Dry	63.8	1.24	64.3	1.24	63.1	1.07	

TABLE 8. CONTINUED

		Region						
		Western		Central		Eastern		
Variable	Season	Mean	S.E.	Mean	S.E.	Mean	S.E.	Significance
SG[d], g/cm^3	Rainy	1.71	.06	1.91	.06	1.82	.05	R[**],SD(R)[**],C_1[**]
	Dry	1.82	.06	1.85	.06	1.75	.05	

[a]Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Standard error of least squares means.

[c]S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

[d]Specific gravity.

[**]P<.01.

[*]P<.05.

[+]P<.10.

TABLE 9. PERCENTAGE OF BONE SAMPLES DEFICIENT IN MACROMINERALS, ASH AND SPECIFIC GRAVITY[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Ca. %	< 24.5	Rainy	96.7	90.0	75.0	96.0
		Dry	70.0	73.3	95.0	77.0
P. %	< 11.5	Rainy	96.7	96.7	92.5	95.0
		Dry	96.7	93.3	92.5	94.0
Ash, %	< 69.8	RAiny	100.0	93.3	65.0	92.0
		Dry	90.0	63.3	92.5	96.0
SG[c]. g/cm^3	< 1.69	Rainy	30.0	3.3	20.0	19.0
		Dry	10.9	10.0	27.5	17.0

[a] Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions. respectively, for each of the seasons

[b] Concentration or value below which is deficient (Little, 1972; McDowell. 1985d).

[c] Specific gravity.

In both seasons, the average of bone calcium concentrations (dry, fat-free basis) in all regions were below the level suggested as critical (24.5%). Furthermore, individual evaluation of samples indicated that 86 and 77% of all samples analyzed were deficient in calcium for the rainy and dry seasons, respectively. The significant incidence of calcium deficiency indicated by bone calcium is not in agreement with the low incidence of calcium deficiency in blood plasma. This phenomenon, in part, may be attributed to the fact that blood calcium is controlled by hormonal mechanisms (Guyton, 1966) so that only in extreme deficiency would blood calcium be low (NCMN, 1973; Boris et al., 1978).

The average bone phosphorus concentrations in all regions were below the critical level of 11.5% for normal cattle (Little, 1972). Overall percentages of deficient bone phosphorus for the rainy and dry seasons, respectively, were 95 and 94%. Cohen (1973) suggested that bone provides a more reliable method for assessing calcium and phosphorus than blood.

The percentage of samples below the critical concentration suggested by McDowell (1985d) for bone ash (66.8% dry, fat-free basis) was 92 for all regions for the rainy season. Similar results were also obtained for the dry season, in which an overall 86% of samples were below the critical concentration. Since the majority components in bone ash are calcium and phosphorus (Ammerman et al, 1974; Maynard et al., 1979) the low concentration of bone ash may be attributed to the fact that bone calcium and phosphorus were also found to be low.

Regional differences ($P<.05$) were found for bone specific gravity in the rainy season, but were not found in the dry season. The overall percentage of bone samples below the critical level of 1.66 g/cm^3 (McDowell, 1985d) was 18 for the rainy season and 17 for the dry season

Relationship of minerals

Gross correlation coefficients of minerals in the soil, forage, blood and bone; and between forage and soil, blood and forage, bone and forage, and blood and bone macrominerals are presented in appendix tables 23 through 30. Partial correlation coefficients for the same variables are shown in appendix tables 35 through 42. Considering values of correlation coefficients (r) $\geq|.5|$ at $P<.05$, the gross correlation of minerals found were as follows: soil potassium and iron ($r=.501$), soil phosphorus and iron ($r=-.527$), forage calcium and iron ($r=.613$), and bone calcium and ash ($r=.519$). However, if the seasonal and/or regional factors have an effect on any of the stated minerals, then the estimated correlations could be misleading. The partial correlation was found only for forage calcium and iron ($r=.575$).

It is important to point out the negative correlation between phosphorus and iron in soils. High levels of one of those elements could adversely effect the availability of the other and its subsequent uptake by plants. The few correlations ($r \geq |.5|$, $P<.05$) of minerals within and between animal tissues observed in this study demonstrated the problem of finding significant correlation coefficients between soil, forage and animal tissues as indicated by Conrad et al. (1980).

Summary

A study was conducted to determine the macromineral status of grazing cattle in three climatic regions of the province of South Sulawesi, Indonesia. Soil, forage, blood and rib bone samples were collected at three, three and four districts within the Western, Central and Eastern regions, respectively, in February-March and August-September of 1987. Sampling periods corresponded to the end of the rainy and dry seasons in each region. The percentages of macromineral and crude protein concentrations below levels regarded as critical (in parentheses) and suggestive of deficiency for the Western, Central and Eastern regions, respectively, for the rainy season were as follow: Soil--calcium (71 ppm) 0, 0, 0; potassium (62 ppm) 0, 0, 17; magnesium (30 ppm) 0, 0, 0; phosphorus (17 ppm) 100, 44, 42;

Forage--calcium (.30%) 28, 33, 17; potassium (.80%) 0, 6, 17; magnesium (.20%) 44, 33, 17; sodium (.06%) 33, 50, 42; phosphorus (.25%) 89, 56, 54; crude protein (7%) 11, 0, 17; Blood--plasma calcium (8 mg/dl) 17, 13, 5; serum magnesium (2 mg/dl) 20, 20, 3; plasma phosphorus (4.5 mg/dl) 17, 0, 30; Bone (dry, fat-free basis)--calcium (24.5%) 97, 900, 75, phosphorus (11.5%) 97, 99, 93; ash (66.8%) 100, 93, 85. In dry season, the percentages were as follows: Soil--calcium (71 ppm) 0, 0, 0; potassium (42 ppm) 0, 13, 8; magnesium (30 ppm) 0, 0, 0, phosphorus (17 ppm) 100, 44, 42; Forage--calcium (.30%) 39, 33, 25; potassium (.80%) 0, 0, 13; magnesium (.20%) 33, 0, 25; sodium (.06%) 0, 78, 46; phosphorus (.25%) 89, 33, 46; crude protein (7%) 33, 22, 33; Blood--plasma calcium (8 mg/dl) 10, 7, 13; serum magnesium (2 mg/dl) 0, 0, 5; plasma phosphorus (4.5 mg/dl) 7, 27, 33; Bone (dry, fat-free basis)--calcium (24.5%) 70, 73, 85; phosphorus (11.5%) 87, 93, 93; ash (66.8%) 80, 83, 93. Based on these analyses, macrominerals most likely deficient in both seasons were phosphorus and calcium in all regions, in addition to sodium in the Central and Eastern regions.

CHAPTER V
MINERAL STATUS OF GRAZING CATTLE IN SOUTH SULAWESI, INDONESIA: II. MICROMINERALS

Introduction

In many tropical countries, livestock often do not receive mineral supplements. Mineral supplementation, if any, is limited to common salt (McDowell et al., 1984). It has been reported that trace element imbalances, along with poor husbandry and inadequate diets frequently contribute to sub-clinical deficiencies in grazing ruminants (Conrad et al., 1980).

On the basis of clinical signs (Tillman, 1981) and the limited number of studies reported (Panggabean et al., 1982; Sutrisno et al., 1983; Prabowo et al., 1983; Kumagai et al., 1989; Panggabean and Towers, 1989) it may be concluded that in addition to phosphorus deficiency in Indonesia, there are marginal deficiencies of iodine, copper, selenium, manganese and zinc. However, Indonesia is a country with large climatic, geographical and vegetation differences so that mineral status of livestock is likely to differ largely among regions. The objective of this study was to evaluate the micromineral status of grazing cattle in three climatic regions of South Sulawesi, Indonesia.

Experimental Procedure

Soil, forage and animal tissue samples were collected from ten different districts within three climatic regions in South Sulawesi, Indonesia during the rainy and dry seasons. For each season, collections were made at three, three and four districts within the Western, Central and Eastern regions, respectively. Sampling periods were February-March and August-September of 1987, corresponded to the end of rainy and dry seasons in each region.

Samples of 30 soils, 60 forages and 100 blood and liver samples from slaughtered animals were obtained for each of the sampling periods. The animals sampled were male Bali cattle, that were three to four years old and weighed in the range of 250 to 300 kg; slaughtered at slaughterhouses in the various districts. Animals which had been sampled were traced back to the original owners in each district where samples of soil and forage were collected from the grazed pastures.

Soils were sampled according to the technique described by Bahia (1978), with samples analyzed according to the procedures used by the IFAS extension soil testing laboratory at the University of Florida, Gainesville (Rhue and Kidder, 1983). Soil samples were analyzed for copper, iron, manganese and zinc. Minerals were extracted from soils using the Mehlich I extracting solution method

(.05 N HCl + .025 N H_2SO_4). Forage samples were processed according to methods described by Fick et al. (1979) and were analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc. Blood serum samples were analyzed for copper, selenium and zinc. Preparation of the liver samples were carried out as described by Fick et al. (1979). The solutions were then analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc

Copper, iron, manganese and zinc were determined by atomic absorption spectrophotometry (Perkin-Elmer Corp., 1982). Cobalt and molybdenum were determined by flameless atomic absorption spectrophotometry (Perkin-Elmer Corp., 1984). Selenium determination was carried out by a modified fluorometric technique (Whetter and Ullrey, 1978).

Data obtained in this study were analyzed statistically using a mixed model (Snedecor and Cochran, 1980) with the General Linear Models (GLM) procedure of the SAS System (SAS Institute Inc , 1987). Gross and partial correlation coefficients were estimated for minerals in the soil, forage, blood and liver; and between forage and soil, blood and forage, liver and forage, and blood and liver microminerals.

Results and Discussion

Soil Analyses

Results of soil micromineral analyses as related to season and region are shown in table 10 and the percentages of deficient soil samples are presented in table 11. No seasonal differences ($P > .10$) were found for all microminerals analyzed in soils.

There was no regional effect ($P > .10$) in extractable soil copper. However, variations ($P < .01$) due to the district effect were found for soil copper concentrations. The copper concentration of soil samples below the critical level of .3 ppm (Rhue and Kidder, 1983), recommended for Florida soils, was found only in the Central region. The overall samples deficient in extractable soil copper for the rainy and dry seasons, respectively, were 7 and 3%. Sanders (1982) indicated that as the pH increases, the quantity of copper adhered to soil components increased and the proportion of copper in soil solution as cupric ion decreased. Since there were no seasonal differences in soil pH (Chapter IV), it is understandable that soil copper concentrations were also found to be similar in both seasons.

Regional differences ($P < .01$) were found for soil iron concentrations. Soils from the Western region were higher ($P < .01$) in iron concentrations than those from the Eastern.

TABLE 10. SOIL MICROMINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	Significance[c]
Cu, ppm	Rainy	1.9	.42	1.7	.42	2.6	.36	$D(R)^{**}$
	Dry	1.3	.42	1.4	.42	3.3	.36	
Fe, ppm	Rainy	85.2	10.6	35.2	10.6	33.3	9.2	R^{**},$D(R)^{*}$,C_1^{+}, C_2^{**}
	Dry	111.9	10.6	34.4	10.6	49.0	9.2	
Mn, ppm	Rainy	13.3	10.0	102.2	10.0	49.3	8.6	$D(R)^{**}$,C_1^{+}
	Dry	36.5	10.0	78.8	10.0	47.2	8.6	
Zn, ppm	Rainy	3.7	2.3	6.9	2.3	5.9	2.0	$D(R)^{+}$,$SD(R)^{*}$
	Dry	5.5	2.3	7.2	2.3	4.7	2.0	

[a] Least squares means of 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

**P<.01.

*P<.05.

$^{+}$P<.10

TABLE 11. PERCENTAGE OF SOIL SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Cu, ppm	< .3	Rainy	0.0	22.2	0.0	6.7
		Dry	0.0	11.1	0.0	3.3
Fe, ppm	< 2.5	Rainy	0.0	11.1	0.0	3.3
		Dry	0.0	11.1	0.0	3.3
Mn, ppm	< 5	Rainy	0.0	11.1	0.0	3.3
		Dry	0.0	11.1	0.0	3.3
Zn, ppm	< 1	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0

[a] Percentages based on 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient, based on recommendations for Florida soils (Viets and Lindsay, 1973; Rhue and Kidder, 1983).

The Central region had lower ($P<.05$) soil iron, in comparison to the other two regions. The iron concentration of soil samples below the critical level suggested by Viets and Lindsey (1973) was found only in the Central region. Of all samples analysed in both seasons, only 3% were deficient in iron. Lindsey (1972) indicated that the solubility of iron in soils is largely controlled by the solubility of hydrous iron (III) oxides. Therefore, these relatively high amounts of extractable soil iron in the Western region may explain the low availability of phosphorus to plants (Chapter IV).

Soil manganese concentrations for the Central region were higher ($P<.10$) than those for the other two regions. The manganese concentrations of soil samples below the suggested critical level of 5 ppm (Khue and Ziddar, 1983) were found only in the Central region at 11% in both the rainy and dry seasons. It is important to mention that the mountainous Central region is characterized by soils of volcanic origin (Muljadi, 1977; cited by Adiningsih et al., 1988). Thus, it may explain the relatively high concentrations of manganese in soils from this region, although the concentrations also varied ($P<.01$) due to the district effect.

Extractable soil zinc was not different ($P>.10$) among regions for either season. However, variations were found, due to the district ($P<.10$) and the interaction of season by district ($P<.05$) effects. Individual evaluation of samples based on the critical level of 1 ppm for normal plant growth (Rhue and Kidder, 1983), when pH is below 6.5, indicated none of the samples analyzed were deficient in zinc during both the rainy and dry seasons.

Forage Analyses

The results of forage micromineral analyses as related to season and region are shown in table 12. The percentages of forage samples deficient in microminerals are presented in table 13. Seasonal differences were observed for cobalt ($P<.05$), copper ($P<.10$) and molybdenum ($P<.05$). Forage cobalt concentrations also were affected ($P<.01$) by the season and region interaction.

With the exception of phosphorus and copper, cobalt deficiency is the most severe mineral limitation to grazing livestock in tropical countries (McDowell et al., 1984). In this study, however, none of individual samples were found below the critical level of .1 ppm suggested by McDowell (1985d) for cobalt deficiency. Furthermore, forage cobalt was not different ($P>.10$) among regions in either the rainy and dry season. Mtimuni (1982) suggested that there is a readily available cobalt in soil for plants grow even on cobalt-deficient soils. Similarly, Reid and Horvath (1980) illustrated that the level of cobalt in soil does not necessarily indicate its availability to plants.

TABLE 12. FORAGE MICROMINERAL CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean^{a}	S.E.^{b}	Mean	S.E.	Mean	S.E.	Significance^{c}
Co, ppm	Rainy	.31	.0002	.44	.0002	.42	.0002	S^{*},SR^{**},$D(R)^{**}$
	Dry	34	.0002	.42	.0002	.41	.0002	
Cu, ppm	Rainy	9.9	2.8	22.9	2.8	14.2	2.4	S^{*}.$D(R)^{**}$.$SD(R)^{**}$
	Dry	8.7	2.8	15.9	2.8	10.3	2.4	
Fe, ppm	Rainy	608	146	530	146	555	126	$D(R)^{**}$,$SD(R)^{**}$
	Dry	876	146	488	146	815	126	
Mn, ppm	Rainy	95	49	85	49	155	42	$D(R)^{**}$.$SD(R)^{**}$
	Dry	80	49	74	49	154	42	
Mo. ppm	Rainy	.75	.19	.42	.19	1.75	.17	S^{*},R^{*}.$D(R)^{**}$,C_1^{*}. C_2
	Dry	.31	.19	.28	.19	1.25	.17	
Se. ppm	Rainy	.08	.11	.39	.11	.33	.10	R^{*},$D(R)^{**}$,$SD(R)^{**}$ C_2
	Dry	.11	.11	.48	.11	.82	.10	

TABLE 12. CONTINUED

		Region						
		Western		Central		Eastern		
Variable	Season	Mean	S.E.	Mean	S.E.	Mean	S.E.	Significance
Zn, ppm	Rainy	25	5	38	5	38	4	D(R)[**], SD(R)[**]
	Dry	30	5	48	5	35	4	

[a] Least squares means of 6 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

[**] P<.01.

[*] P<.05

[+] P<.10

TABLE 13. PERCENTAGE OF FORAGE SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Co. ppm	< .1	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Cu. ppm	< 8	Rainy	61.1	33.3	4.2	30.0
		Dry	55.6	33.3	16.7	33.3
Fe, ppm	< 50	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Mn. ppm	< 40	Rainy	5.6	27.8	8.3	13.3
		Dry	22.2	27.8	12.5	20.0
Mo. ppm	> 6	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Se. ppm	< .2	Rainy	88.9	0.0	50.0	46.7
		Dry	100.0	33.3	25.0	50.0
Zn. ppm	< 30	Rainy	88.9	38.9	33.3	51.7
		Dry	44.4	22.2	29.2	31.7

[a] Percentages based on 6 samples/district with 3, 3 and 4 districts within Western. Central and Eastern regions, respectively. for each of the seasons.

[b] Concentration below which is deficient or above which. in the case of Mo. is excessive (McDowell, 1985d). based on requirements of beef cattle (NRC. 1984).

Forage copper concentrations were not different ($P>.10$) among the three regions. However, variations ($P<.01$) were found, due to the district and the interaction of season by district effects. A high percentage of samples was found below the critical level suggested by McDowell (1985d) for forage copper (8 ppm) in the Western region. The percentages of samples below the critical concentration in this region for the rainy and dry season, were 61 and 56, respectively. With the exception of phosphorus, deficiency of copper is the most severe limitation to grazing livestock throughout extensive regions of the tropics (McDowell et al., 1984).

Forage molybdenum concentrations showed regional differences ($P<.05$). The Central region had lower ($P<.10$) forage molybdenum concentrations than the other two regions. Higher ($P<.05$) concentrations were found in the Eastern than in the Western region. Molybdenum concentrations of all forage samples analyzed were below the toxic level of 6 ppm (McDowell, 1985d). The average copper-to-molybdenum ratio in forages was greater than the value of 2:1 suggested by Miltimore and Mason (1971) as the point at which a lower ratio could have resulted in conditioned copper deficiency.

Forage iron concentrations were similar ($P>.10$) in all regions for either season. However, variations ($P<.01$) were found, due to the district and the interaction of season by district effects. Individual evaluation of samples based on iron requirements of 50 ppm (McDowell, 1985d) indicated that none of the forage samples were deficient in iron. The zero incidence of iron deficiency in forages during both the rainy and dry seasons is in agreement with generally adequate concentrations of soil iron.

Forage manganese concentrations were similar (P>.10) in all regions for both seasons. Evaluation of samples based on a dietary manganese requirement of 40 ppm (McDowell, 1985d) indicated a number of deficient samples during both the rainy and dry seasons. Of all samples analyzed, 13 and 20% were deficient in this microminerel for the rainy and dry seasons, respectively. Although extractable soil manganese was high in the Central region, this region also showed the highest percentage of forage samples deficient in manganese among the three regions, at 28% for both the rainy and dry seasons. Variations (P<.01) were found, due to the district and the interaction of season by district effects.

Regional differences (P<.10) were found for forage selenium concentrations. Lower (P<.05) concentrations were found in the Western region than in the Eastern region. Individual evaluation of forage samples based on the critical level of .2 ppm for selenium (McDowell, 1985d) indicated that the percentage of samples below the critical concentration during the rainy season in each region were as follows: Western, 89%; Central, 0%; and Eastern, 50%. A similar tendency was found during the dry season in which the percentage of deficient samples in each region were as follows: Western, 100%, Central, 33; and Eastern, 25%. It appeared that the Western region was the region with the most potential selenium deficiency problem.

Forage zinc concentrations varied (P<.01) due to the district and the interaction of season by district effects. Individual evaluation of samples based on the critical value of 30 ppm for zinc (McDowell, 1985d) also indicated that the Western was the region with the most potential for zinc deficiency problem. During the rainy season, 89% of samples from this region were below the critical level, while in the dry season the percentage was 44. The overall percentage of samples found to be deficient also decreased from 52 in the rainy season to 32 during the dry season. In contrast to the statement of Underwood (1981) that zinc concentration in plants decreases with advancing maturity, in this study, a lower incidence of zinc deficiency in the dry season than the rainy season was detected.

Animal Tissue Analyses

Blood. Blood micromineral concentrations as related to season and region are presented in table 14. Percentages of deficient blood samples are shown in table 15. Seasonal differences were found for serum selenium (P<.05) and zinc (P<.01) concentrations. For both elements, concentrations were higher in the rainy season than in the dry season.

TABLE 14. BLOOD SERUM MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	Significance[c]
Cu, μg/ml	Rainy	.61	.06	.80	.06	.75	.06	R^{*}, $D(R)^{**}$, $SD(R)^{**}$
	Dry	.61	.06	.76	.06	.69	.06	C_1, C_2
Se, μg/ml	Rainy	.11	.02	.14	.02	.13	.01	S^{*}, R^{*}, $D(R)^{**}$,
	Dry	.05	.02	.10	.02	.11	.01	$SD(R)^{**}$, C_2
Zn, μg/ml	Rainy	.90	.08	1.15	.08	.93	.07	S^{**}, $D(R)^{**}$,
	Dry	.67	.08	.84	.08	.70	.07	$SD(R)^{**}$, $C_1^{\dagger}$

[a] Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

** $P< .01$.

* $P<.05$.

† $P<.10$.

TABLE 15. PERCENTAGE OF BLOOD SERUM SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Serum Cu, µg/ml	< .65	Rainy	43.3	20.0	27.5	30.0
		Dry	70.0	26.7	45.0	47.0
Serum Se, µg/ml	< .03	Rainy	0.0	0.0	0.0	0.0
		Dry	10.0	0.0	0.0	3.0
Serum Zn, µg/ml	< .6	Rainy	0.0	0.0	12.5	5.0
		Dry	26.7	3.3	27.5	20.0

[a] Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient (McDowell, 1985d).

Regional differences ($P<.05$) were found for serum copper concentrations. The concentration for the Central region was higher ($P<.05$) than the other two regions. Cattle from the Western region had lower ($P<.05$) serum copper concentrations than those from the Eastern region. Individual evaluation of samples based on the .65 µg/ml serum copper critical level (McDowell, 1985d) indicated a higher percentage of samples below the critical concentration in the Western in comparison to the other two regions. The percentages for the Western region were 43 in the rainy season and 70 in the dry season. Of all samples analyzed, 30 and 47% were deficient during the rainy and dry seasons, respectively.

Regional differences ($P<.05$) were found for serum selenium. Lower ($P<.05$) concentrations were found in the Western region in comparison to the Eastern region. Of all blood samples analyzed for selenium during the dry season, only 3% were deficient, but all of them came from the Western region. These results are in agreement with the results on forage analyses in the Western region, where the highest incidence of low forage selenium concentration was found. The average blood selenium concentration of samples from this region, however, was above the critical level of .03 µg/ml (McDowell, 1985d) suggesting a deficiency.

The average serum zinc values in all regions was above the .6 µg/ml suggested by McDowell (1985d) as the critical level, and no differences ($P > .10$) were detected among regions for both seasons. However, as serum zinc concentrations were lower ($P < .01$) for the dry than the rainy season, individual evaluation of samples indicated an increased incidence of zinc deficiency in the dry season. The percentage of samples below the critical level were 5 for the rainy season, and 20 for the dry season. The highest incidence of deficiency (28%) was in the Eastern region during the dry season. Conrad (1978) indicated that serum or plasma zinc is rapidly and markedly reduced with severely deficient diets, although concentrations are not greatly influenced by marginally deficient diets.

Liver. Liver micromineral concentrations as related to season and region are presented in table 16 with percentages of liver samples deficient in microminerals presented in table 17. Seasonal differences were detected for liver cobalt ($P < .05$), copper ($P < .10$), manganese ($P < .01$) and molybdenum ($P < .10$) concentrations.

Liver cobalt concentrations were similar ($P > .10$) for all regions. Variations were found, due to the district ($P < .01$) and the season by district interaction ($P < .05$) effects. Cattle from the Central region had lower ($P < .10$) liver cobalt than those from the other two regions. None of the cattle liver samples analyzed were deficient in cobalt, based on a critical level of .05 ppm suggested by McDowell (1985d). Although cobalt deficiencies have been reported as

TABLE 16. LIVER MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	Significance[c]
Co, ppm	Rainy	.51	.04	.43	04	.48	.03	S^*, $D(R)^{**}$, $SD(R)^*$, C_1
	Dry	.54	.04	.50	.04	.59	.03	
Cu, ppm	Rainy	72	12	138	12	100	10	S^*, R^{**}, $D(R)^{**}$, $SD(R)^{**}$, C_1^{**}, C_2^*
	Dry	43	12	114	12	98	10	
Fe, ppm	Rainy	363	25	270	25	316	21	$D(R)^{**}$, $SD(R)^*$
	Dry	411	25	326	25	322	21	
Mn, ppm	Rainy	9.2	1.11	6.4	1.11	9.4	.96	S^{**}, R^{**}, $D(R)^{**}$, $SD(R)^{**}$, C_1
	Dry	13.8	1.11	7.9	1.11	13.1	.96	
Mo, ppm	Rainy	3.1	.16	2.9	.16	3.7	.14	S^*, R^*, $D(R)^{**}$, C_2
	Dry	3.1	.16	3.2	.16	4.1	.14	
Se, ppm	Rainy	.41	06	.56	.06	1.14	.06	R^{**}, $D(R)^{**}$, $SD(R)^*$, C_1, C_2
	Dry	.39	.06	.57	.06	1.04	.06	

TABLE 16. CONTINUED

		Region						
		Western		Central		Eastern		
Variable	Season	Mean	S.E.	Mean	S.E.	Mean	S.E.	Significance
Zn, ppm	Rainy	119	5.2	111	5.2	112	4.5	D(R)**,SD(R)*
	Dry	116	5.2	108	5.2	104	4.5	

[a] Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, C_1=Central vs Western and Eastern, C_2=Western vs Eastern.

**P<.01.

*P<.05.

+P<.10.

TABLE 17. PERCENTAGE OF LIVER SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Co, ppm	< .05	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Cu, ppm	< 75	Rainy	56.7	0.0	30.0	29.0
		Dry	100.0	0.0	12.5	35.0
Fe, ppm	< 180	Rainy	0.0	0.0	5.0	2.0
		Dry	0.0	3.3	7.5	4.0
Mn, ppm	< 6	Rainy	20.0	50.0	10.0	25.0
		Dry	0.0	20.0	0.0	6.0
Mo, ppm	> 4	Rainy	16.7	3.3	45.0	24.0
		Dry	10.0	0.0	57.5	26.0
Se, ppm	< .25	Rainy	30.0	0.0	0.0	9.0
		Dry	23.3	6.7	0.0	9.0
Zn, ppm	< 84	Rainy	0.0	10.0	0.0	3.0
		Dry	3.3	6.7	2.5	4.0

[a] Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient or above which, in the case of Mo, is excessive (McDowell, 1985d).

one of the most severe limitation to grazing livestock in tropical countries (McDowell et al., 1984), no cobalt deficiency was indicated in this study. Similar situations were also found in Malawi (Mtimuni, 1982) and Guatemala (Tejada et al., 1987a).

Regional differences ($P<.01$) were found in liver copper. Higher ($P<.01$) concentrations were found for the Central region than the other two regions. Cattle from the Western region had lower ($P<.05$) liver copper than those from the Eastern region. The average liver copper concentration in the Western region was below the critical level of 75 ppm (McDowell, 1985d) in both seasons. Individual evaluation of samples from this region for the rainy season indicated that 57% of the samples analyzed were deficient. An even higher incidence of deficiency (100%) was encountered in the dry season. The overall percentage of copper deficient liver samples was 29 in the rainy season in comparison to 35 in the dry season; none of the deficient samples came from the Central region. According to Owen (1982), liver is the central organ in copper metabolism; it removes ionic copper from blood, excretes a portion into bile, synthesizes ceruloplasmin with another portion, and the remainder could be stored as copper in the liver. Furthermore, liver copper is reported to be the best criterion for assessing the copper status of cattle (NCMN, 1973). Soil, forage, blood serum and liver analyses for the dry season in the Western region indicated 0, 56, 70 and 100% incidence copper deficiency, respectively. A similar observation was made by Tejada et al. (1987a) in their study in Guatemala. Therefore, it seems that soil copper does not have any value in aiding the diagnosis of copper deficiencies in animals.

Regional differences ($P<.05$) were found in liver molybdenum. Concentrations for the Eastern region were higher ($P<.10$) than those for the Western region. The average liver molybdenum concentration for the Eastern region in the dry season was above the 4 ppm level suggested by McDowell (1985d) as excessive. During the rainy season, the percentage of liver samples above the critical level for molybdenum in the Eastern region was 45; while in the dry season, the percentage was 58. These results may indicate the negative interrelationship between copper and molybdenum, as suggested by Underwood (1981), which could exist in this region. However, the average liver copper concentration of samples from the Eastern region was also high in both the rainy and dry seasons.

Liver iron concentrations were similar ($P>.10$) in all regions for either season. The average values in all regions were much greater than the level of 180 ppm suggested by McDowell (1985d) as indicating a deficiency. Therefore, the overall percentage of samples below the critical level was only 2%. During the dry season, no difference (P>.05) was found for liver iron concentration among regions. Liver is the central point of mineral metabolism in the animal body and is thus a useful organ for estimation of iron status (Boyazoglu et al., 1972). These results, therefore, suggest that iron deficiency is not a problem for grazing cattle in South Sulawesi, Indonesia.

Regional differences (P<.01) were found in liver manganese. Concentrations for the Central region were lower (P<.01) than those for the other two regions. The incidence of samples below the critical level of 6 ppm (McDowell, 1985d) for different regions were as follows: Western, 20%; Central, 50%; and Eastern, 10%. Of all samples analyzed for the rainy season, 25% were deficient. Regional differences (P<.05) in liver manganese were found in the dry season, with he lowest value observed in the Central region. As liver manganese concentrations were higher (P<.01) for the dry season than the rainy season, a decreased incidence of manganese deficiency was observed in the dry season. The overall percentage of deficient samples for the dry season was 6. McDowell et al. (1978) suggested that manganese deficiency can best be detected when there is a combination of less than 6 ppm manganese in the liver and less than 20 ppm in the diet. Results on manganese concentration of liver samples from the Central region are in agreement with the results on forage manganese concentration of samples from the same region. Both liver and forage samples showed the highest incidence of deficiencies among regions, despite the relatively high concentration of extractable soil manganese.

Regional differences (P<.01) were found in liver selenium. Higher (P<.01) concentrations were found in the Eastern region in contrast to the Western region. Cattle from the Central region had lower (P<.05) liver selenium concentrations than those from the other two regions. The average value of liver selenium in each region was also found to be above the .25 ppm critical level suggested by McDowell (1985d). The overall incidence of liver samples deficient in selenium was 9% for both seasons with none of them coming from the Eastern region.

Variations were found in liver zinc concentrations, due to the district (P<.01) and the interaction of season and district (P>.05) effects. The overall percentage of samples below the critical level of 84 ppm for liver zinc (McDowell, 1985d) was 3 for the rainy season and 4 for the dry season.

Relationship of minerals

The relationship of minerals in the soil, forage and blood, and between blood and forage minerals have been discussed in Chapter IV. Gross correlation coefficients of microminerals in the liver and between forage and soil, liver and forage, and blood and liver microminerals are presented in appendix tables 31 through 34. Partial correlation coefficients for the same variables are shown in appendix tables 43 through 48.

Gross correlations ($r \geq |.5|$, $P<.05$) were present for forage copper and soil manganese ($r=.711$); forage molybdenum and soil copper ($r=.575$); liver selenium and forage molybdenum ($r=.543$); and between blood zinc and liver manganese ($r=-.517$). However, there were no partial correlation coefficients (r) $\geq |.5|$ at $P<.05$.

Summary

A study was conducted to determine the micromineral status of grazing cattle in three climatic regions of the province of South Sulawesi, Indonesia. Soil, forage, blood and liver samples were collected at three, three and four districts within the Western, Central and Eastern regions, respectively, in February-March and August-September of 1987. Sampling periods corresponded to the end of the rainy and dry seasons in each region. The percentages of micromineral concentrations below levels regarded as critical (in parentheses) and suggestive of deficiency for the Western, Central and Eastern regions, respectively, for the rainy season were as follow: Soil--copper (.3 ppm) 0, 22, 0; iron (2.5 ppm) 0, 11, 0; manganese (5 ppm) 0, 11, 0; zinc (1 ppm) 0, 0, 0; Forage--cobalt (.1 ppm) 0, 0, 0; copper (8 ppm) 61, 33, 4; iron (50 ppm) 0, 0, 0; manganese

(40 ppm) 8, 28, 8; selenium (.2 ppm) 89, 0, 50; zinc (30 ppm) 89, 39, 33; Blood serum--copper (.65 μg/ml) 43, 20, 28; selenium (.03 μg/ml) 0, 0, 0; zinc (.8 μg/ml) 0, 0, 13; Liver--cobalt (.05 ppm) 0, 0, 0; copper (75 ppm) 57, 0, 30; iron (180 ppm) 0, 0, 5; manganese (6 ppm) 20, 50, 10; selenium (.25 ppm) 30, 0, 0; zinc (84 ppm) 0, 10, 0. In the dry season, the percentages were as follows: Soil--copper (.3 ppm) 0, 11, 0; iron (2.5 ppm) 0, 11, 0; manganese (5 ppm) 0, 11, 0; zinc (1 ppm) 0, 0, 0; Forage--cobalt (.1 ppm) 0, 0, 0; copper (8 ppm) 58, 33, 17; iron (50 ppm) 0, 0, 0; manganese (40 ppm) 22, 28, 13; selenium (.2 ppm) 100, 33, 25; zinc (30 ppm) 44, 22, 29; Blood serum--copper (.85 μg/ml) 70, 27, 45; selenium (.03 μg/ml) 10, 0, 0; zinc (.8 μg/ml) 27, 3, 28; Liver--cobalt (.05 ppm) 0, 0, 0; copper (75 ppm) 100, 0, 13; iron (180 ppm) 0, 3, 8; manganese (6 ppm) 0, 20, 0; selenium (.25 ppm) 0, 7, 0; zinc (84 ppm) 3, 7, 3. Based on the analyses, microminerals most likely deficient in both the rainy and dry seasons for each region were as follows: Western--copper, selenium and zinc; Central--manganese and copper; Eastern--selenium, copper and zinc. Some degree of molybdenum excess was found in the Eastern region.

CHAPTER VI
MINERAL STATUS COMPARISONS BETWEEN GRAZING CATTLE AND WATER BUFFALO IN SOUTH SULAWESI, INDONESIA

Introduction

For ages, the water buffalo has been recognized as a domestic draft animal. It is also a potential source of quality meat which may be produced more cheaply than from any other domestic animal (Cockrill, 1982). In Indonesia, water buffaloes are second to cattle as meat producing animals (Tillman, 1981). However, high demands for meat are causing excessive slaughtering so that the buffalo population is decreasing (Sutardi et al., 1982).

Comparative studies between water buffaloes and cattle have been done in many countries, but few have been in the area of mineral nutrition. As recommended by NRC (1981), those comparisons will extend recognition of the water buffalo's value, especially under difficult conditions where it may exceed cattle in productivity and profitability.

The present study was conducted to evaluate and compare the mineral status of grazing cattle and water buffalo in South Sulawesi, Indonesia.

Experimental Procedure

Soil, forage and animal tissue samples were collected from four districts in the province of South Sulawesi, Indonesia during the rainy and dry seasons. The districts were Gowa, Polmas, Enrekang and Bone. Sampling periods were February-March and August-September of 1987, corresponded to the end of rainy and dry seasons in each district.

Animal tissue (blood, bone, liver) samples were collected at slaughterhouses in the various districts. Samples of 40 (10/district) cattle were obtained for each of the sampling periods in addition to the following number of samples of buffaloes: Gowa, 15 and 19; Polmas, 12 and 17; Enrekang, 12 and 15; Bone 19 and 23; for the rainy and dry seasons, respectively. The animals sampled were male Bali cattle (250-300 kg) and buffaloes of the water or swamp breed commonly found throughout Southeast Asia (300-350 kg), aged three to four years old. Animals which had been sampled were traced back to the original owners in each district where samples of soil and forage were collected from the grazed pastures. Samples of 12 (3/district) soils and 24 (6/district) forages were obtained for each of the sampling periods.

Soils were sampled according to the technique described by Bahia (1978), with samples analysed according to the procedures used by the IFAS extension soil testing laboratory at the university of Florida, Gainesville (Rhue and Kidder, 1983). Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium, phosphorus, copper, iron, manganese and zinc. Minerals were extracted from soils using the Mehlich I extracting solution method (.05 N HCl + .025 N H_2SO_4). Forage samples were processed according to methods described by Fick et al. (1979) and were analyzed for calcium, potassium, magnesium, sodium, phosphorus, cobalt, copper, iron, manganese, molybdenum, selenium and zinc. Blood plasma samples were analyzed for calcium and phosphorus, while serum was analyzed for magnesium, copper, selenium and zinc. Bones were prepared according to the procedure of Fick et al. (1979) to obtain fat-free bone ash for calcium, magnesium and phosphorus analyses. Preparation of the liver samples were carried out as described by Fick et al. (1979). The solutions were then analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc.

Calcium, potassium, magnesium, sodium, copper, iron, manganese and zinc were determined by atomic absorption spectrophotometry (Perkin-Elmer Corp., 1982); and cobalt and molybdenum by flameless atomic absorption spectrophotometry (Perkin-Elmer Corp., 1984). Phosphorus was analyzed using the colorimetric method of Harris and Popst (1954) while selenium determination was carried out by a modified fluorometric technique (Whetter and Ullrey, 1979).

Additionally, bone specific gravity was measured using a Mettler ME-40290 kit (Mettler Instruments AG, CH-8606 Greifensee, Switzerland), expressed in g/cm^3; and forage crude protein concentrations were determined by measuring total nitrogen following the method described by Gallaher et al. (1975) and the Technicon Industrial Systems (1978).

Data obtained in this study were analyzed statistically using a mixed model (Snedecor and Cochran, 1980) with the General Linear Models (GLM) procedure of the SAS System (SAS Institute Inc., 1987).

Results and Discussion

Soil Analyses

Results of soil analyses as related to season are presented in table 15. The results as related to season and district are presented in appendix table 47.

Seasonal differences were found for soil organic matter ($P<.05$), soluble salts ($P<.05$), calcium ($P<.01$), potassium ($P<.01$) and phosphorus ($P<.05$) concentrations. The concentrations for organic matter were higher in the dry season while those for soluble salts, calcium, potassium and phosphorus were higher in the rainy season, in comparison to the other season. However, individual evaluation of samples based on the suggested critical levels for each elements (Breland, 1976; Rhue and Kidder, 1983) indicated that none

TABLE 18. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON

		Season					
		Rainy		Dry			
Variable	Critical level[a]	Mean[b]	% Def.[c]	Mean	% Def.	S.E.[d]	Significance[e,f]
OM[g], %		4.9		8.8		.23	S^{*}
pH		5.8		8.0		.27	
SS[h], ppm		590		433		25	S^{*}
Al, ppm		1215		1247		37	
Ca, ppm	< 71	1085	0.0	652	0.0	32	S^{**},D^{**}
K, ppm	< 62	178	0.0	158	8.3	3	S^{**},D^{**}
Mg, ppm	< 30	364	0.0	329	0.0	50	D^{**},SD^{**}
Na, ppm		32		27		3.0	D^{**}
P, ppm	< 17	18	58.3	18	58.3	11	S^{*},D^{*}
Cu, ppm	< .3	1.5	16.7	1.5	8.3	.51	D^{**},SD^{**}
Fe, ppm	< 2.5	43.7	8.3	57.8	8.3	5.8	D^{**}
Mn, ppm	< 5	41.9	8.3	54.0	8.3	7.0	D^{**}

TABLE 18. CONTINUED

Variable	Critical level	Season				S.E.	Significance
		Rainy		Dry			
		Mean	% Def.	Mean	% Def.		
Zn, ppm	< 1	9.2	0.0	6.6	0.0	2.7	SD*

[a] Concentration below which is deficient, based on recommendations for Florida soils (Viets and Lindsay, 1973; Breland, 1976; Rhue and Kidder, 1983).

[b] Means of 3 samples/district with 4 districts for each of the seasons.

[c] Percentage of deficient samples.

[d] Standard error of means.

[e] S=season, D=district, SD=season x district interaction.

[f] See appendix table 47 for details on D and SD effects.

[g] Organic matter.

[h] Soluble salts.

***P<.01.

**P<.05.

*P<.10.

of the soil samples analyzed were calcium deficient in either season, and the percentage of potassium deficient samples was small.

Among the soil minerals analyzed, phosphorus exhibited the highest incidence of deficiency. Compared to the critical value of 17 ppm, recommended for Florida soils (Rhue and Kidder, 1983), the percentage of deficient soil samples was 58, for both the rainy and dry seasons. Tropical soils are generally deficient in phosphorus (Volkweiss, 1978). Soil aluminum is important in reduction of available phosphorus and the consequent uptake by plants under acid conditions, at pH below 5.5 (Sanchez, 1976). Although soil extractable aluminum was found to be relatively high, soil pH was above 5.5. Therefore, it appeared that this high concentration of aluminum did not have much effect on the reduction of available soil phosphorus and the consequent uptake by plants as indicated by Sanchez (1976). Reid and Horvath (1980) indicated that maximum rate of cation absorption occurs at pH 5 to 7.

Forage Analysis

Results of forage analyses as related to season are presented in tables 19. The results as related to season and district are presented in appendix table 48.

Seasonal differences (P<.05) were found for forage iron, molybdenum and crude protein, with concentrations for

TABLE 19. FORAGE MINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON

		Season					
		Rainy		Dry			
Variable	Critical level^{a}	Mean^{b}	% Def.^{c}	Mean	% Def.	S.E.^{d}	Significance^{e,f}
Ca, %	< .3	.34	41.7	.43	16.7	.06	D^{*},SD^{*}
K, %	< .8	1.66	8.3	1.48	4.2	.07	D^{**}
Mg, %	< .2	.26	25.0	.27	6.3	.02	D^{**},SD^{*}
Na, %	< .06	.07	54.2	.06	45.8	.01	D^{*}
P, %	< .25	.23	62.5	.24	41.7	.03	D^{**},SD^{*}
Co, ppm	< .1	.39	0.0	.38	0.0	.01	D^{**}
Cu, ppm	< 6	11.0	41.7	9.1	37.5	2.0	D^{**},SD^{**}
Fe, ppm	< 50	444	0.0	712	0.0	46	S^{*},D^{**}
Mn, ppm	< 40	96	25.0	95	20.6	19	D^{**}.SD^{*}
Mo, ppm	> 6	.63	0.0	.32	0.0	.05	S^{*},D^{*}
Se, ppm	< .2	.26	50.0	.24	75.0	.11	D^{**}.SD^{**}
Zn, ppm	< 30	35	50.0	32	37.5	4	D^{*}

TABLE 19. CONTINUED

		Season					
		Rainy		Dry			
Variable	Critical level	Mean	% Def.	Mean	% Def.	S.E.	Significance
CP[g], %	< 7	9.7	0.0	7.6	33.3	.28	S*

[a] Concentration below which is deficient or above which, in the case of Mo, is excessive (Milford and Minson, 1966; McDowell, 1985d), based on mineral requirements of beef cattle (NRC, 1984).

[b] Means of 6 samples/district (3 samples/district for CP) with 4 districts for each of the seasons.

[c] Percentage of deficient samples.

[d] Standard error of means.

[e] S=season, D=district, SD=season x district interaction.

[f] See appendix table 48 for details on D and SD effects.

[g] Crude protein.

**P<.01.

**P<.05.

*P<.10.

iron higher in the dry season while those for molybdenum and crude protein higher in the rainy season, compared to the other season. In both seasons, the average concentration for potassium, magnesium, cobalt, iron and manganese were above the suggested critical levels for each elements (McDowell, 1985d), and the incidence of deficiency was less than 25%. Variations (P<.10) also were found in many of the minerals analyzed, due to the district and/or the interaction of season by district effects, but the percentages of deficient samples were small.

In contrast to the adequate soil calcium level, individual evaluation of samples based on the .3% critical level (McDowell, 1985d) indicated low calcium concentrations for both seasons. The percentage of samples below the critical level was 42 in the rainy season and 17 in the dry season. Similar situations were reported in Malawi (Mtimuni, 1982), Colombia (Vargas et al., 1984) and Guatemala (Tejada et al., 1987b).

Compared to the critical level of .08% (McDowell, 1985d), the average forage sodium concentrations were marginal for both seasons. The percentages of forage samples below the critical level were 54 for the rainy season and 46 for the dry season.

As found in soils, phosphorus showed the highest incidence of deficiency among minerals analyzed in forages. Individual evaluation of samples based on the critical level of .25% (McDowell, 1985d) indicated that forages were deficient in phosphorus at 63% in the rainy season and at 42% in the dry season. As mentioned earlier, it appeared that the high aluminum concentrations found in soils did not have much effect on the reduction of phosphorus uptake by plants, since soil pH was above 5.5.

The average copper concentration in forages was above the 8 ppm critical level suggested by McDowell (1985d) in both the rainy and dry seasons. However, 40% of samples analyzed for both seasons were below the critical level indicating copper deficiency.

The average molybdenum concentration in the rainy season was almost twice as much as that in the dry season. In both seasons, however, none of forage samples analyzed showed molybdenum concentration above the 6 ppm level, regarded as excessive (McDowell, 1985d).

A high incidence of deficiency was found in forage selenium in both the rainy and dry seasons. Compared to the critical level of .2 ppm (McDowell, 1985d), the percentage of selenium deficient forage samples were 50 in the rainy season and 75 in the dry season.

Although the average zinc concentration in forages were above the 30 ppm critical level (McDowell, 1985d) for both seasons, a considerable number of samples was found below the critical level. The percentages were 50 in the rainy season and 38 in the dry season.

Higher ($P<.05$) crude protein concentrations were found in the rainy season, in comparison to those of the dry season. Thus, it was observed that the percentage of forage samples below the critical level of 7% (Milford and Minson, 1966) was higher in the dry season than in the rainy season. This is in agreement with Gomide (1978) who found decreased forage nitrogen, phosphorus and potassium with increasing forage maturity.

It is important to point out that in both seasons, forage iron concentrations were high. This may adversely affect utilization of other minerals such as copper, phosphorus, zinc and manganese (Standish et al., 1969, 1971; Campbell et al., 1974; Humphries et al., 1983; Prabowo et al., 1988) by ruminants.

Animal Tissue Analysis

Blood. Blood mineral concentrations as related to season and animal species are presented in table 20. The results as related to season, district and animal species are presented in appendix table 49. The average concentrations of blood minerals for both species in either season were above the suggested critical levels for cattle (McDowell, 1985d), for each element.

Seasonal differences ($P<.01$) were found for plasma calcium, with concentrations in the dry season higher than those in the rainy season. In either season, however,

TABLE 20. BLOOD MINERAL CONCENTRATIONS AS RELATED TO SEASON AND ANIMAL SPECIES

		Animal species						
		Cattle			Buffalo			
Variable^a	Season	Mean^b	S.E.^{c}	% Def.^{d}	Mean	S.E.	% Def.	Significance^{e,f}
Ca, mg/dl	Rainy	8.4	.06	15.0	8.3	.05	25.9	S^{**},D^{**},DA^{*}
	Dry	8.7	.06	2.5	8.7	.04	2.7	
Mg, mg/dl	Rainy	2.3	.02	12.5	2.4	.02	5.2	D^{**},SD^{**}
	Dry	2.5	.02	0.0	2.5	.02	0.0	
P, mg/dl	Rainy	5.6	.13	25.0	5.4	.11	43.1	D^{**},SD^{**}
	Dry	5.2	.13	27.5	5.0	.10	29.7	
Cu, µg/ml	Rainy	.77	.03	27.5	.86	.03	15.5	D^{**},SD^{**},DA^{**}, SDA^{*}
	Dry	.66	.03	50.0	.70	.02	36.5	
Se, µg/ml	Rainy	.12	.01	0.0	.05	.01	10.3	D^{**},A^{*},SD^{**},DA^{**}, SDA^{*}
	Dry	.10	.01	5.0	.06	.01	28.4	

TABLE 20. CONTINUED

		Animal species						
		Cattle			Buffalo			
Variable	Season	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Significance
Zn, µg/ml	Rainy Dry	1.00 .75	.06 .06	0.0 10.0	.97 .70	.05 .04	0.0 25.7	S*,D**,SD**,SDA**

[a] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[b] Least squares means of the following number of samples: rainy season, 40 cattle and 58 buffaloes; dry season, 40 cattle and 74 buffaloes; from 4 districts.

[c] Standard error of least squares means.

[d] Percentage of deficient samples, based on the following critical levels: Ca, 8 mg/dl, Mg, 2 mg/dl; P, 4.5 mg/dl; Cu, .65 µg/ml; Se, .03 µg/ml; Zn, .6 µg/ml (McDowell, 1985d), suggested for cattle.

[e] S=season, D=district, A=animal species, SD=season x district interaction, DA=district x animal species interaction, SDA=season x district x animal species interaction.

[f] See appendix table 49 for details on D, SD, DA and SDA effects.

$^{**}P<.01$

$^{*}P<.05$.

$^{+}P<.10$.

plasma calcium concentrations for cattle and buffaloes were similar (P>.10). Similar serum calcium concentrations between Charolais cattle and water buffaloes were observed by Merkel (1989) in Florida.

Serum magnesium was not different (P>.10) between seasons and animal species. Variations (P<.01) were found, due to the district and the interaction of season by district effects. The concentrations were in the range of 1.8 to 3.2 mg/dl considered as normal for cattle (Underwood, 1981). Patel et al. (1971) reported buffalo cows having 2.9 mg/dl of serum magnesium.

No differences (P>.10) were found in plasma phosphorus for both species in either season. Merkel (1989) reported higher serum phosphorus in cattle than buffaloes, with concentrations averaging 5.2 mg/dl for cattle and 3.9 mg/dl for buffaloes. Hanif et al. (1984) recorded a range of plasma phosphorus from 4.5 to 4.8 mg/dl in buffalo cows in Pakistan. In Florida, Collins (1978) reported an average value of 6.9 mg/dl for buffalo serum phosphorus.

Similar (P>.10) concentrations of serum copper were observed for cattle and buffaloes in both the rainy and dry seasons. Variations were found, due to the district (P<.01), the interaction of season by district (P<.01), the interaction of district by animal species (P<.01) and the interaction of season by district by animal species (P<.10) effects. However, a considerable number of samples below the critical level of .65 μg/ml suggested for cattle (McDowell, 1985d) were found in the dry season, with cattle having higher percentage than buffaloes (50 vs 37). Buffalo serum copper concentrations have been reported to range from 1.07 to 1.12 μg/ml (Chandolia and Verma, 1987), although lower values of .84 μg/ml (Hanif et al., 1984) and .67 μg/ml (Merkel, 1989) have also been reported.

Species differences (P<.10) were observed for serum selenium with cattle having higher concentration, more than twice as much as those in buffaloes. However, the average concentrations for both species in either season were above the critical level of .03 μg/ml (McDowell, 1985d) for cattle. Merkel (1989) reported a similar tendency of higher serum selenium in cattle than buffaloes. Plasma selenium concentration of .03 μg/ml has been reported in Egyptian buffaloes (Gazia and Wegger, 1980).

Seasonal differences (P<.05) were found for serum zinc, with concentrations in the rainy season higher than those in the dry season. In either season, however, cattle and buffaloes had similar (P>.10) serum zinc concentrations. None of the samples analyzed for the rainy season indicated a deficiency (<.6 μg/ml), but in the dry season, 10 and 26 % of cattle and buffalo samples, respectively, were below the critical level suggested by McDowell (1985d) for cattle.

Bone. Bone mineral concentrations and specific gravity as related to season and animal species are presented in table 21. The results as related to season, district and animal species are presented in appendix table 50. For all variables analyzed in bone samples, no differences ($P>.10$) were found due to either season or animal species effect. However, the effects of district ($P<.01$), season by district interaction ($P<.01$) and season by animal species interaction ($P<.10$) were observed in bone specific gravity. Variations ($P<.01$) also were found, due to season by district interaction effects, for bone calcium, magnesium and ash concentrations. The percentage of deficiencies based on suggested critical levels (Little, 1972; McDowell, 1985d) for all minerals analyzed in each season and animal species were high.

In both seasons, the average bone calcium concentrations (dry, fat-free basis) for both species were below the suggested critical level (24.5%) for cattle. Furthermore, individual evaluation of cattle samples indicated that 90 and 70% were deficient in the rainy and dry seasons, respectively. Compared to the same critical level, buffalo samples showed a similar percentage of deficiency. The significant incidence of calcium deficiency indicated by bone calcium is not in agreement with the low incidence of calcium deficiency in blood plasma. This phenomenon, in part, may be attributed to the fact that

TABLE 21. BONE MINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON AND ANIMAL SPECIES

		Animal species						
		Cattle			Buffalo			
Variable	Season	Mean[a]	S.E.[b]	% Def.[c]	Mean	S.E.	% Def.	Significance[d,e]
Ca. %	Rainy	22.8	.06	90.0	22.8	.05	89.7	SD**
	Dry	23.4	.06	70.0	23.4	.05	71.6	
Mg. %	Rainy	.47	.01		.47	.01		SD**
	Dry	.42	.01		.42	.01		
P, %	Rainy	10.0	.17	100.0	10.2	.14	94.8	
	Dry	10.3	.17	92.5	10.2	.13	91.9	
Ash, %	Rainy	62.3	.63	95.0	62.8	.53	93.1	SD**
	Dry	64.3	.63	82.5	64.0	.47	83.8	

TABLE 21. CONTINUED

		Animal species						
		Cattle			Buffalo			
Variable	Season	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Significance
SG[f], g/cm^3	Rainy	1.83	.03	17.5	1.72	.03	31.0	D[**], SD[**], SA[+]
	Dry	1.83	.03	17.5	1.87	.02	13.5	

[a] Least squares means of the following number of samples: rainy season, 40 cattle and 58 buffaloes; dry season, 40 cattle and 74 buffaloes, from 4 districts.

[b] Standard error of least squares means.

[c] Percentage of deficient samples, based on the following critical levels: Ca, 24.5%; P, 11.5%; Ash, 66.8%; SG, 1.68% (Little, 1972; McDowell, 1985d), suggested for cattle.

[d] D=district, SD=season x district interaction, SA=season x animal species interaction.

[e] See appendix table 50 for details on D and SD effects.

[f] Specific gravity.

[**] $P<.01$

[+] $P<.10$.

blood calcium is controlled by hormonal mechanisms (Guyton, 1966) so that only in extreme deficiency would blood calcium be low (NCMN, 1973; Boris et al., 1978).

The average bone phosphorus concentrations for both species in either season were below the critical level of 11.5% for normal cattle (Little, 1972). The percentages of deficient bone phosphorus for the cattle were 100 and 95, in the rainy and dry seasons, respectively. Similar percentages were found for buffaloes. Cohen (1973) suggested that bone provides a more reliable method for assessing calcium and phosphorus than blood.

Similar (P>.10) bone magnesium concentrations were found in both seasons for both species. The average concentration, however, was below the range of .67 to .70% considered as normal (Blaxter and Sharman, 1955) or the .60 to .73% values reported by Lebdosoekojo et al. (1980) for grazing young bulls.

The percentage of samples below the critical bone ash concentration suggested by McDowell (1985d) for cattle (66.8% dry, fat-free basis) were 95 and 83 in the rainy and dry seasons, respectively. Compared to the same critical level, buffalo samples showed similar results in which 93 and 84% of samples were below the critical concentration, in the rainy and dry seasons, respectively. Since the majority components in bone ash are calcium and phosphorus (Ammerman et al, 1974; Maynard et al., 1979) the low content of bone ash may be attributed to the fact that bone calcium and phosphorus were also found to be low.

The incidence of deficiencies for bone specific gravity, based on the 1.GA g/cm^3 value regarded as critical, were relatively small in comparison to the other bone analyses. Little (1972) suggested that calcium or phosphorus content per unit volume has greater sensitivity than per unit fresh weight, moisture-free and fat-free basis, since in the last two, water and fat contents were not taken into account.

Liver. Liver mineral concentrations as related to season and animal species are presented in table 22. The results as related to season, district and animal species are presented in appendix table 51. Animal species differences were observed for cobalt (P<.05), copper (P<.10) and selenium (P<.05) concentrations. Cattle had higher liver selenium, but lower cobalt and copper concentrations than buffaloes.

None of the cattle and buffalo liver samples analyzed for the rainy and dry seasons were found below the critical level of .05 ppm for cobalt (McDowell, 1985d) suggested for cattle. Despite the cobalt deficiencies reported in many tropical countries (McDowell et al., 1984), it seems that this is not a problem in South Sulawesi, Indonesia.

As the buffaloes had higher (P<.10) liver copper concentrations than cattle, a smaller percentage of samples

TABLE 22. LIVER MINERAL CONCENTRATIONS AS RELATED TO SEASON AND ANIMAL SPECIES

		Animal species						
		Cattle			Buffalo			
Variable	Season	Mean[a]	S.E.[b]	% Def[c]	Mean	S.E.	% Def.	Significance[d,e]
Co, ppm	Rainy	.46	.03	0.0	.53	.02	0.0	A^{*}
	Dry	.48	.03	0.0	.56	.02	0.0	
Cu, ppm	Rainy	133	8	10.0	171	7	3.4	S^{*},D^{**},A^{*},SD^{*},
	Dry	93	8	27.5	138	6	9.5	DA^{*}
Fe, ppm	Rainy	281	5	2.5	329	4	0.0	S^{*},D^{**},DA^{*}
	Dry	311	5	5.0	377	4	4.1	
Mn, ppm	Rainy	9.0	.18	25.0	8.8	.15	20.7	D^{**},SD^{**}
	Dry	11.0	.18	5.0	11.1	.14	5.4	
Mo, ppm	Rainy	3.0	.05	10.0	3.1	.05	13.8	D^{**},SD^{*}
	Dry	3.3	.05	15.0	3.4	.04	20.3	
Se, ppm	Rainy	.68	.03	15.0	.51	.02	17.2	D^{**}.A^{*}
	Dry	.64	.03	17.5	.45	.02	32.4	

TABLE 22. CONTINUED

		Animal species						
		Cattle			Buffalo			
Variable	Season	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Significance
Zn, ppm	Rainy	114	1.7	5.0	113	1.4	5.2	S*,D**
	Dry	102	1.7	7.5	106	1.4	9.5	

[a] Least squares means of the following number of samples. rainy season, 40 cattle and 58 buffaloes; dry season, 40 cattle and 74 buffaloes; from 4 districts.

[b] Standard error of least squares means.

[c] Percentage of deficient (excessive, in the case of Mo) samples, based on the following critical levels: Co, .05 ppm; Cu, 75 ppm; Fe, 180 ppm; Mn, 6 ppm; Mo, 4 ppm, Se, .25 ppm; Zn, 84 ppm (McDowell, 1985d), suggested for cattle.

[d] S=season, D=district, A=animal species, SD=season x district interaction, DA=district x animal species interaction, SDA=season x district x animal species interaction.

[e] See appendix table 51 for details on D, SD, DA and SDA effects.

[**] P<.01.

[*] P<.05.

[+] P<.10.

below the critical level of 75 ppm (McDowell, 1985), suggested for cattle, was found in buffaloes than cattle. The percentages for cattle and buffaloes, respectively, were 10 and 3 in the rainy season, and 28 and 10 in the dry season.

No differences (P>.10) between seasons and animal species were found for liver molybdenum concentrations. Variations were found, due to the district (P<.01) and the interaction of season by district (P<.05) effects. Individual evaluation of samples, based on the critical level of 4 ppm (McDowell, 1985d) suggested for cattle, indicated that 10 and 15% of cattle liver samples were excessive in the rainy and dry seasons, respectively. Compared to the same critical level, buffalo liver samples showed a slightly higher percentage than those of cattle in both seasons. These conditions may indicate the negative interrelationship between copper and molybdenum (Underwood, 1981). In this study, however, liver copper concentrations were also found to be above the suggested critical level for a deficiency.

Seasonal differences (P<.10) were found for liver iron, with concentrations in the dry season higher than those in the rainy season. However, the average liver iron concentrations for both species in both seasons were above the critical level of 180 ppm (McDowell, 1985d) suggested for cattle, and the incidence of deficiency was small. As generally reported, nutritional iron deficiency is not a problem for grazing ruminants (Underwood, 1977)

Liver manganese concentrations were not different ($P>.10$) between seasons and animal species. Variations were found, due to the district ($P<.01$) and the interaction of season by district ($P<.05$) effects. The average concentrations for both species in both seasons were above the 6 ppm level indicating deficiency for cattle (McDowell, 1985d). These results are in agreement with results of forage analyses. McDowell et al. (1978) suggested that manganese deficiency can best be detected when there is a combination of less than 6 ppm manganese in the liver and less than 20 ppm in the diet.

Cattle had higher ($P<.05$) liver selenium than buffaloes. However, the average liver concentrations for both species in both season were above the critical level of 25 ppm (McDowell, 1985d) suggested for cattle.

Seasonal differences ($P<.05$) were found for liver zinc, with higher concentrations found in the rainy season than in the dry season. In both seasons, however, the incidence of deficiency for both species based on the critical level of 84 ppm (McDowell, 1985d) suggested for cattle, were less than 10%.

There were no data found in the literature on bone and liver mineral analyses comparisons between cattle and water buffaloes.

Summary

A study was conducted to evaluate and compare the mineral status of grazing Bali cattle and water buffaloes in four districts in the province of South Sulawesi, Indonesia. Soil, forage and animal tissue (blood, bone, liver) samples were collected in February-March and August-September of 1987, corresponded to the end of the rainy and dry seasons in each district.

Phosphorus was the most likely deficient mineral in soils in both the rainy and dry seasons. Seasonal differences ($P<.05$) were found for soil organic matter, soluble salts, calcium, potassium and phosphorus concentrations. Forages were found to be low to deficient in selenium, phosphorus, sodium, zinc, copper and calcium concentrations. Seasonal variations ($P<.05$) were found for forage iron, molybdenum and crude protein concentrations.

The average blood mineral concentrations for cattle and buffaloes in both seasons were above the critical levels suggested for cattle. Seasonal variations were found for plasma calcium ($P<.01$) and serum zinc ($P<.05$) concentrations. Concentrations of serum selenium were higher ($P<.10$) for cattle than buffaloes. Compared to the suggested critical levels for cattle, high incidence of deficiencies were found for bone calcium and phosphorus. Bone specific gravity was affected ($P<.10$) the interaction

of season and animal species. Liver mineral analyses indicated that cattle had higher ($P<.05$) liver selenium, but lower liver cobalt ($P<.05$) and copper ($P<.10$) concentrations than buffaloes. Seasonal differences were found for liver iron ($P<.10$) and zinc ($P<.05$). The incidence of liver mineral deficiencies, based on the suggested critical levels for cattle, were less than 30% for both species in both seasons. Some degree of molybdenum excess (>4 ppm) was observed in the liver of cattle and buffaloes.

It is suggested that minerals most likely limiting ruminant production in South Sulawesi, Indonesia are phosphorus, sodium, calcium, selenium, copper, zinc and manganese. Although differences between cattle and water buffalo were found in this study, comparison with results reported in the literature demonstrates large variability. Therefore, dracstic species differences could not be concluded.

CHAPTER VII
SUMMARY AND CONCLUSIONS

A study was conducted in the province of South Sulawesi, Indonesia to determine the mineral status of grazing ruminants by evaluating the concentrations of minerals in soils, plants and animal tissues. This study provided information as the basis for future efficient and low-cost mineral supplementation programs.

Soil, forage and animal tissue samples were collected from ten administrative districts within three climatic regions during both the rainy and dry seasons. Collections were made at three, three and four districts within the Western, Central and Eastern regions, respectively, for each season. The sampling periods were February-March and August-September of 1987, corresponded to the end of rainy and dry seasons in each region. A total of 30 soil, 60 forage, and 100 cattle tissue (blood, bone and liver) samples were obtained for each of the sampling periods. In addition, 58 and 74 buffalo tissue samples were obtained in the rainy and dry seasons, respectively, from four of the ten districts included in this study.

Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium, phosphorus, copper, iron, manganese and zinc. Forage samples were analyzed for the same minerals, except aluminum, in addition to cobalt, molybdenum, selenium and crude protein. Blood plasma samples were analyzed for calcium and phosphorus, while serum was analyzed for magnesium, copper, selenium and zinc. Bone was analyzed for calcium, magnesium, phosphorus, ash and specific gravity. Finally, liver samples were analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc.

Seasonal differences were found in soil analyses, with concentrations in the rainy season higher for soluble salts ($P<.01$), calcium ($P<.01$), potassium ($P<.05$) and sodium ($P<.01$), but lower for organic matter ($P<.01$); in comparison to those in the dry season. Soils from the Central region were lower ($P<.05$) in extractable sodium than those from the other two regions. In the Western region, concentrations for soil phosphorus, averaging 9.8 and 9.3 ppm for the rainy and dry seasons, respectively, were the lowest ($P<.05$), while those for soil iron were the highest ($P<.05$) among the three regions. Phosphorus was found to be the most likely deficient mineral in soils, in both the rainy and dry seasons, especially in the Western region.

As found in soils, phosphorus exhibited the highest incidence of deficiency in forages. Forage phosphorus concentrations in the Western region were the lowest (P<.10) among regions. A negative correlation (r=-.527, P<.01) between phosphorus and iron found in soils may explain the low soil phosphorus and its subsequent uptake by plants. In the dry season, forage sodium concentrations in the Central region, averaging .04% showed the highest incidence of deficiency. Forage copper concentrations varied (P<.01), due to the district within region effect. In the Western region, 61 and 56% of samples analyzed for the rainy and dry seasons, respectively were copper deficient (< 8 ppm). Forage selenium concentrations of samples from the Western region were lower (P<.05) than those from the Eastern region. The Western region also had the highest incidence of forage zinc deficiency among the three regions. In both seasons, minerals most likely to be deficient in forages were phosphorus, selenium, sodium, zinc and copper. Seasonal differences were found for cobalt (P<.05), copper (P<.10), molybdenum (P<.05) and crude protein (P<.05).

Seasonal differences (P<.05) were observed in cattle blood minerals, with higher concentrations in the rainy season found for serum selenium and zinc, but higher in the dry season found for serum magnesium; in comparison to those in the other season. Serum magnesium concentrations were also affected (P<.10) by the interaction of season and region. Regional differences (P<.05) were observed for serum copper and selenium, but the overall incidence of deficiency for all blood minerals analyzed were less than 25% in all regions for both seasons, with the exception of serum copper. Serum copper analyses showed 30 and 70% incidence of deficiencies during the rainy and dry seasons, respectively. Cattle from the Western region had the lowest ($P<.05$) serum copper concentrations, averaging .61 μg/ml for both seasons.

Cattle bone variables did not vary ($P>.10$) among regions during either season, with the exception of specific gravity, that exhibit lower ($P<.01$) values in the Western and Eastern regions, compared to those in the Central region. However, the incidence of deficiency, indicated by concentrations below the suggested critical levels, was high for phosphorus and calcium analyzed for both seasons.

Seasonal differences were detected for cattle liver cobalt ($P<.05$), copper ($P<.10$), manganese ($P<.01$) and molybdenum ($P<.10$). Cattle from the Western region had the lowest ($P<.05$) liver copper concentrations among the three regions. The Western region also had lower ($P<.10$) cattle liver molybdenum concentrations than the Eastern region. Liver manganese concentrations of cattle from the Central region were lower ($P<.10$) than those from the other two regions. The Eastern region had the highest ($P<.05$) liver selenium concentration among regions. Thus, high incidence of deficiencies were found in both seasons for copper in the Western region, and in the rainy season for manganese in the central region. In the dry season, the average cattle liver molybdenum concentrations in the Eastern region were above the critical level of 4 ppm, which would be considered as excessive.

Gross correlations ($r \geq |.5|$, $P<.05$) of minerals were observed for soil potassium and iron ($r=.501$), soil phosphorus and iron ($r=-.527$), forage calcium and iron ($r=.613$), forage phosphorus and crude protein ($r=.553$), bone calcium and ash ($r=.519$), forage copper and soil manganese ($r=.711$), forage molybdenum and soil copper ($r=.575$), liver selenium and forage molybdenum ($r=.543$), and for blood zinc and liver manganese ($r=.517$). However, if the seasonal and/or regional factors have an effect on any of the stated minerals, the estimated correlations could be misleading. The partial correlation was found only for forage calcium and iron ($r=.575$).

On the basis of cattle and water buffalo tissue analyses in four districts, animal species differences were detected. Cattle had higher blood serum ($P<.10$) and liver ($P<.05$) selenium, but lower liver cobalt ($P<.05$) and copper ($P<.10$) concentrations than buffaloes. Bone specific gravity was affected ($P<.10$) by the interaction of season and animal species.

Considering only the minerals analyzed and taking into account their greatest value in assessing mineral deficiencies in ruminants, the minerals most likely limiting ruminant production in the province of South Sulawesi, Indonesia during the rainy and dry seasons, in decreasing order, were phosphorus, copper, sodium, selenium, calcium, zinc and manganese. Copper is the mineral which deserves special attention in formulating mineral supplements, due to variations of its concentration in forages within all regions, in addition to some degree of molybdenum excess in the Eastern region.

APPENDIX A

SUPPLEMENTARY TABLES

TABLE 23. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL CORRELATION COEFFICIENTS[a]

	OM[b]	pH	SS[c]	Al	Ca	K	Mg	Na	P	Cu	Fe	Mn	Zn
OM	1.060												
pH	.096	1.006											
SS	.040	.019	1.006										
Al	-.073	-.194	-.196	1.000									
Ca	-.277*	.012	.256*	.089	1.000								
K	-.142	-.054	-.267*	.123	.121	1.000							
Mg	-.017	.115	-.008	-.064	.103	-.204*	1.000						
Na	-.367**	-.122	.064	.057	.405	.258*	.009	1.000					
P	.026	.027	.264	-.042	.171	-.466**	.265*	-.065	1.000				
Cu	-.224*	.066	.037*	-.029	-.141	.156	.111	.223*	.076	1.000			
Fe	.059	.206	-.037	.061	-.163	.661**	-.360**	-.002	-.527**	.042	1.000		
Mn	.324*	.166	.145	-.066	.046	-.065	-.075	-.194	.195	.094	.051	1.060	
Zn	.156	-.053	.176	.043	.266*	-.200	.144	-.135	-.037	-.395**	-.071	.212	1.000

[a] Gross correlations of 60 samples.

[b] Organic matter

[c] Soluble salts

**P<.01, *P<.05, +P<.10

TABLE 24. FORAGE MINERAL CORRELATION COEFFICIENTS[a]

	Ca	K	Mg	Na	P	Co	Cu	Fe	Mn	Mo	Se	Zn
Ca	1.000											
K	-.035	1.000										
Mg	.110	-.042	1.000									
Na	.120	.366**	-.008	1.000								
P	.075	.118	.226*	-.087	1.000							
Co	.078	-.070	.057	.063	.127	1.000						
Cu	.070	.246**	.288**	.162^{+}	.292**	.046	1.000					
Fe	.613**	.104	.060	.075	.007	-.123	.096	1.000				
Mn	.482**	.056	.279**	.314**	.139	-.059	.120	.459**	1.000			
Mo	.188*	.032	.125	-.052	.153^{+}	.047	-.170^{+}	.105	.272**	1.000		
Se	.055	-.274**	.044	-.222^{+}	.345**	.198*	.112	.017	.065	.313**	1.000	
Zn	.047	.072	.367**	-.049	.225*	.011	.398**	.118	.278**	-.072	.315**	1.000

[a] Gross correlations of 120 samples.

$^{**}P<.01$, $^{*}P<.05$, $^{+}P<.10$.

TABLE 25. BLOOD MINERAL CORRELATION COEFFICIENTS[a,b]

	Ca	Mg	P	Cu	Se	Zn
Ca	1.000					
Mg	.032	1.000				
P	-.081	.098	1.000			
Cu	.009	-.084	-.282**	1.000		
Se	.082	-.188**	-.074	.068	1.000	
Zn	-.032	-.122*	.152*	.223**	.321**	1.000

[a] Gross correlations of 200 samples.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

**P<.01.

*P<.05.

$^{+}$P<.10.

TABLE 26. BONE MACROMINERAL AND SPECIFIC GRAVITY CORRELATION COEFFICIENTS[a]

	Ca	Mg	P	Ash	SG[b]
Ca	1.000				
Mg	-.107	1.000			
P	.422**	.104	1.000		
Ash	.519**	-.372**	.264**	1.000	
SG	.355**	-.253**	.100	.326**	1.000

[a] Gross correlations of 200 samples.

[b] Specific gravity.

$^{**}P<.01$.

TABLE 27. CORRELATION COEFFICIENTS BETWEEN FORAGE MACROMINERALS AND SOIL ANALYSES[a]

	Forage				
	Ca	K	Mg	Na	P
Soil					
OM[b]	-.032	.094	-.035	-.048	.012
pH	-.072	-.141	.048	.007	-.044
SS[c]	.099	-.240*	.215+	.018	-.056
Al	-.138	-.009	-.012	-.129	.082
Ca	-.037	.081	.298*	.215+	.004
K	.098	.457**	-.198	.191	-.098
Mg	.038	-.341**	.037	.087	-.027
Na	-.033	.180	.153	.078	.080
P	-.058	-.487**	.226+	-.298*	.245+
Cu	.217+	-.078	-.018	-.055	.237+
Fe	.233+	.385**	-.118	.228+	-.197
Mn	.018	-.038	-.072	.004	.094
Zn	-.087+	-.031	.193	.279*	-.096

[a] Gross correlations of 80 forage and soil samples.

[b] Organic matter.

[c] Soluble salts.

**P<.01.

*P<.05.

+P<.10.

TABLE 28. CORRELATION COEFFICIENTS BETWEEN BLOOD AND FORAGE MINERALS[a]

	Blood[b]					
	Ca	Mg	P	Cu	Se	Zn
Forage						
Ca	-.119	-.172*	-.139	-.049	.027	-.054
K	-.093	-.099	.128	-.230*	-.083	-.221*
Mg	-.147	.120	-.232*	.277**	.118	.049
Na	-.098	-.228*	.018	-.249**	-.143	-.108
P	.044	-.132	-.003	.049	.411**	-.091
Co	.078	-.181*	-.012	-.048	.039	-.045
Cu	-.061	-.187*	.067	.203*	.138	.336**
Fe	-.088	.081	-.009	-.089	-.182*	-.203
Mn	-.116	-.128	-.209*	.155*	-.017	-.171*
Mo	.014	.084	-.083	.066	.356**	-.029
Se	-.113	-.106	-.119	.141	.220*	.031
Zn	-.130	-.005	-.033	.209*	.026	.111

[a] Gross correlations of 120 blood and forage samples.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

**P<.01.

*P<.05

*P<.10.

TABLE 29. CORRELATION COEFFICIENTS BETWEEN BONE AND FORAGE MINERALS[a]

	Bone				
	Ca	Mg	P	Ash	SG[b]
Forage					
Ca	.004	.075	.012	-.072	.113
K	-.171[+]	-.103	-.122	-.098	-.089
Mg	.181	.005	.100	.112	.139
Na	-.030[*]	-.023	-.175[+]	-.016	-.077
P	-.026	-.106	.027	-.023	.016
Co	.005	-.051	-.056	.018	.025
Cu	-.048	.029	-.055	.040	.131
Fe	.088	-.111	.037	.127	.227[*]
Mn	.007	.007	-.161[*]	-.019	.092
Mo	.139	-.077	.117	.011	-.009
Se	.113	.027	.191[*]	.116	-.013
Zn	.043	.048	.084	.120	.168[+]

[a] Gross correlations of 120 bone and forage samples.

[b] Specific gravity.

[*] P<.05.

[+] P<.10.

TABLE 30. CORRELATION COEFFICIENTS BETWEEN BLOOD AND BONE MINERALS[a]

	Blood[b]					
	Ca	Mg	P	Cu	Se	Zn
Bone						
Ca	.109	.022	-.123+	.055	-.039	-.061
Mg	-.166*	-.072	.104	-.112	.165*	.157*
P	-.025	.038	-.047	-.039	.060	.034
Ash	.151*	.062	-.185**	.133+	-.136+	-.108+
SG[c]	.114	.007	-.127+	.297**	.041	.164

[a] Gross correlations of 200 blood and bone samples.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[c] Specific gravity.

**P<.01.

*P<.05.

+P<.10.

TABLE 31. LIVER MICROMINERAL CORRELATION COEFFICIENTS^{a}

	Co	Cu	Fe	Mn	Mo	Se	Zn
Co	1.000						
Cu	−.123^{+}	1.000					
Fe	.139*	−.363**	1.000				
Mn	.188**	−.250**	.111	1.000			
Mo	.173*	−.049	.028	.103	1.000		
Se	.090	.242**	−.173*	.075	.342**	1.000	
Zn	−.015	.032	.211**	−.096	−.063	−.080	1.000

^{a}Gross correlations of 200 samples.

**P<.01.

*P<.05.

$^{+}$P<.10.

TABLE 32. CORRELATION COEFFICIENTS BETWEEN FORAGE MICROMINERALS AND SOIL ANALYSES^{a}

	Forage						
	Co	Cu	Fe	Mn	Mo	Se	Zn
Soil							
OM^{b}	.202	.446**	.181	-.065	-.339**	.028	.225*
pH	.042	.004	.079	.168	-.102	-.145	-.076
SS^{c}	-.044	.336**	.048	.129	.047	.010	.043
Al	-.076	-.102	-.141	-.254*	-.075	-.041	-.097
Ca	-.034	.169	-.208	.142	.114	-.304*	-.098
K	.008	-.097	.129	-.144	.031	-.297*	-.295*
Mg	.080	-.069	-.304*	.148	.193	.068	-.022
Na	.002	-.161	-.066	.032	.452**	-.230*	-.277*
P	-.034	.156	-.003	.206	.088	.378**	.225*
Cu	-.011	.061	.172	.205	.575**	.380**	-.121
Fe	.200	-.014	.268*	-.094	-.224*	-.325*	-.264*
Mn	.015	.711**	.024	.096	-.098	.201	.291*
Zn	.127	.151	-.170	.122	-.100	.057	.369**

^{a}Gross correlations of 60 forage and soil samples.

^{b}Organic matter.

^{c}Soluble salts.

**P<.01.

*P<.05.

$^{+}$P<.10.

TABLE 33 CORRELATION COEFFICIENTS BETWEEN LIVER AND FORAGE MINERALS^{a}

	Liver						
	Co	Cu	Fe	Mn	Mo	Se	Zn
Forage							
Ca	.129	-.033	-.163^{+}	-.053	.288**	.026	-.086
K	-.060	-.235**	.143	.053	.006	-.207*	.009
Mg	-.086	.326**	-.049	.026	.148	.358**	-.029
Na	.005	-.063	.088	.054	.007	-.107	.117
P	-.167*	.191*	-.151^{+}	-.196*	-.071	.154^{+}	-.232*
Co	.118	.204*	-.094	-.058	.088	.124	-.001
Cu	-.100	.268**	-.014	-.346**	.006	-.019	.004
Fe	.113	-.225	-.016	.161^{+}	.225*	-.093	-.133
Mn	-.088	.171^{+}	-.147	.002	.229*	.397**	.069
Mo	.146	-.072	-.004	.052	.426**	.543**	-.053
Se	.189*	.161^{+}	-.124	-.050	.234*	.325**	-.174^{+}
Zn	.005	.290**	-.034	-.205*	.077	.120	.159^{+}

[a] Gross correlations of 120 liver and forage samples.

$^{**}P<.01$.

$^{*}P<.05$.

$^{+}P<.10$.

TABLE 34. CORRELATION COEFFICIENTS BETWEEN BLOOD AND LIVER MINERALS[a]

	Blood[b]					
	Ca	Mg	P	Cu	Se	Zn
Liver						
Co	.103	.037	.044	-.023	-.093	-.221**
Cu	.076	-.193**	-.360**	.419**	.290**	.256**
Fe	-.012	.216	.216	-.136+	-.159*	-.164**
Mn	-.037	.296**	-.066	-.059	-.422**	-.517**
Mo	-.032	.105	-.049	.014	.121+	-.109
Se	.065	.126+	-.243**	.156*	.356**	-.032
Zn	-.062	.034	.004	.043	-.145*	.025

[a] Gross correlations of 200 blood and liver samples.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

**P<.01.

*P<.05.

+P<.10.

TABLE 35. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MINERAL PARTIAL CORRELATION COEFFICIENTS[a]

	OM[b]	pH	SS[c]	Al	Ca	K	Mg	Na	P	Cu	Fe	Mn	Zn
OM	1.000												
pH	.054	1.000											
SS	-.042	-.065	1.000										
Al	-.103	-.182	-.142	1.000									
Ca	.128	.051	-.073	.204*	1.000								
K	.285*	-.076	-.051	.274*	.444**	1.000							
Mg	.264	.154	-.314*	.187	.203*	.240*	1.000						
Na	-.215	.052	-.001	.175	.281*	.190	.118	1.000					
P	.001	.026	.113	-.043	.157	.031	.047	-.084	1.000				
Cu	-.105	.166	.143	.131	-.051	-.024	.012	.027	-.185	1.000			
Fe	.074	.227	.204	.078	.048	.134	-.045	.020	-.331*	.261	1.000		
Mn	.324*	.105	-.113	-.108	.232	.445**	.121	.193	-.180	-.036	.427**	1.000	
Zn	.101	-.053	-.007	-.051	.318*	.271*	.100	.288	-.383*	-.218	.118	.235	1.000

[a] Error degrees of fredom = 30.

[b] Organic matter.

[c] Soluble salts.

**P<.01, *P<.05, *P<.10.

TABLE 36. FORAGE MINERAL PARTIAL CORRELATION COEFFICIENTS^{a}

	Ca	K	Mg	Na	P	Co	Cu	Fe	Mn	Mo	Se	Zn
Ca	1.000											
K	.040	1.000										
Mg	.280**	.102	1.000									
Na	-.203*	.228*	.130	1.000								
P	.138	.267**	.357**	.040	1.000							
Co	-.026	.173	.078	.138	.011	1.000						
Cu	-.050	.414**	.285**	.348**	.198*	.131	1.000					
Fe	.575**	.031	.126	-.135	.181*	-.102	-.118	1.000				
Mn	.180*	.046	.222*	.119	.199*	-.145	-.253*	.117	1.000			
Mo	.294**	.155	.203*	-.094	.170*	-.013	-.128	.160	.253*	1.000		
Se	.177^{+}	-.004	.236*	.078	.386**	-.158	-.018	.270**	.149	.227*	1.000	
Zn	.173*	.406**	.306**	.189*	.193*	.013	.117	.305**	.389**	.011	.130	1.000

^{a}Error degrees of freedom = 93.

**P<.01, *P<.05, $^{+}$P<.10.

TABLE 37. BLOOD MINERAL PARTIAL CORRELATION COEFFICIENTS[a b]

	Ca	Mg	P	Cu	Se	Zn
Ca	1.000					
Mg	.082	1.000				
P	.076	.153*	1.000			
Cu	-.067	-.052	.058	1.000		
Se	.021	.057	-.055	-.096	1.000	
Zn	-.069	.013	.170*	.112	-.062	1.000

[a] Error degrees of freedom = 17.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

*P<.05.

TABLE 38. BONE MACROMINERAL AND SPECIFIC GRAVITY PARTIAL CORRELATION COEFFICIENTS[a]

	Ca	Mg	P	Ash	SG[b]
Ca	1.000				
Mg	.054	1.000			
P	.420**	.194**	1.000		
Ash	.468**	-.160*	.253**	1.000	
SG	.328**	-.054	.107	.244**	1.000

[a] Error degrees of freedom = 17.

[b] Specific gravity.

**P<.01.

*P<.05.

TABLE 39. PARTIAL CORRELATION COEFFICIENTS BETWEEN FORAGE MACROMINERALS AND SOIL ANALYSES[a]

	Forage				
	Ca	K	Mg	Na	P
Soil					
OM[b]	-0.062	.324*	-.042	.076	.022
pH	-.076	-.101	-.142	-.318*	.125
SS[c]	.028	-.122	-.023	-.156	.018
Al	.013	-.056	-.049	.039	.170
Ca	-.184	.214	-.021	.110	.455**
K	.036	.028	.135	.135	.074
Mg	-.104	.089	-.270+	.067	-.011
Na	-.107	.208	-.328*	.307+	-.007
P	-.179	-.290+	-.132	-.475**	.105
Cu	.120	-.111	-.014	-.045	.064
Fe	.130	.012	.031	.016	.159
Mn	-.072	.285+	-.119	.145	-.022
Zn	.077	.309*	.061	.497**	.151

[a] Error degrees of freedom = 39.

[b] Organic matter.

[c] Soluble salts.

**P<.01.

*P<.05.

+P<.10.

TABLE 40. PARTIAL CORRELATION COEFFICIENTS BETWEEN BLOOD AND FORAGE MINERALS[a]

	Blood[b]					
	Ca	Mg	P	Cu	Se	Zn
Forage						
Ca	-.140	-.005	-.215	.077	.184*	-.037
K	.061	-.194*	-.086	-.043	.020	-.233*
Mg	-.184*	.011	-.180*	.132	.200*	-.098
Na	-.010	-.148	.039	-.190*	.079	.002
P	.067	-.086	-.047	-.021	.384**	-.106
Co	.144	-.070	.023	-.006	-.049	-.118
Cu	.070	-.108	-.046	-.098	.123	.017
Fe	-.137	.068	-.221*	.010	.174*	-.130
Mn	-.042	-.130	.082	.079	.134	-.107
Mo	.066	.080	.077	.178*	.106	-.092
Se	-.140	-.183*	-.184+	.035	.325**	-.118
Zn	-.120	.026	-.084	-.151	.130	-.183+

[a] Error degrees of freedom = 99.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

**P<.01.

*P<.05.

+P<.10.

TABLE 41 PARTIAL CORRELATION COEFFICIENTS BETWEEN BONE AND FORAGE MINERALS[a]

	Bone				
	Ca	Mg	P	Ash	SG[b]
Forage					
Ca	.048	.006	.126	-.035	.166[+]
K	-.122	-.196[*]	-.087	-.054	.135
Mg	.242[*]	-.002	.201[*]	.204[*]	.136
Na	.062	.024	-.102	.028	-.069
P	.051	-.201[*]	.041	-.041	.160
Co	-.020	-.063	-.069	.099	.052
Cu	.099	-.102	-.040	.196[*]	.026
Fe	-.055	-.092	.065	.142	.188[+]
Mn	.064	.077	.001	-.066	.056
Mo	.100	-.161	.100	.007	.164[+]
Se	.014	-.034	.278[**]	.061	.166[+]
Zn	.092	-.003	.119	.159	.195[+]

[a] Error degrees of freedom = 99.

[b] Specific gravity.

[**] P<.01.

[*] P<.05.

[+] P<.10.

TABLE 42. PARTIAL CORRELATION COEFFICIENTS BETWEEN BLOOD AND BONE MINERALS[a]

	Blood[b]					
	Ca	Mg	P	Cu	Se	Zn
Bone						
Ca	.042	-.010	-.063	.015	.004	-.050
Mg	-.064	.063	-.031	-.010	-.017	.010
P	-.117	.058	-.126[*]	-.017	-.016	-.058
Ash	.053	-.001	-.062	.054	-.013	.057
SG[c]	-.009	.069	.045	.065	.112	.004

[a] Error degrees of freedom = 179.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[c] Specific gravity.

[*] $P < .10$.

TABLE 43. LIVER MICROMINERAL PARTIAL CORRELATION COEFFICIENTS[a]

	Co	Cu	Fe	Mn	Mo	Se	Zn
Co	1.000						
Cu	.126[+]	1.000					
Fe	.112	-.083	1.000				
Mn	-.048	.012	.026	1.000			
Mo	-.078	.150[*]	-.088	.060	1.000		
Se	-.016	.066	-.030	-.001	.038	1.000	
Zn	.049	.076	.096	-.097	.119	.034	1.000

[a] Error degrees of freedom = 17.

[*] P<.05.

[+] P<.10.

TABLE 44. PARTIAL CORRELATION COEFFICIENTS BETWEEN FORAGE MICROMINERALS AND SOIL ANALYSES[a]

	Forage						
	Co	Cu	Fe	Mn	Mo	Se	Zn
Soil							
OM[b]	.472**	.592	-.006	-.351*	-.289+	.206	-.063
pH	-.147	-.159	-.029	.100	-.137	.014	.130
SS[c]	-.252	.124	.062	-.288+	-.016	.196	-.366*
Al	-.199	.044	.024	.005	.070	-.173	-.029
Ca	.053	.201	.001	.093	-.033	.029	.132
K	.346*	.394*	-.093	-.039	-.248	-.258	-.056
Mg	.086	.210	-.147	-.098	-.282+	-.278+	-.120
Na	-.243	-.081	-.071	.217	-.023	-.278+	-.058
P	.017	-.195	.104	-.127	-.370*	.087	-.010
Cu	-.294*	.009	-.022	.043	.119	-.079	-.083
Fe	-.192	.260	.039	.025	.112	.032	-.196
Mn	.135	.495**	-.196	-.183	-.078	-.216	-.235
Zn	.172	.208	-.105	.228	.171	-.032	.157

[a] Error degrees of freedom = 39.

[b] Organic matter.

[c] Soluble salts.

** P<.01.

* P<.05.

+ P<.10.

TABLE 45. PARTIAL CORRELATION COEFFICIENTS BETWEEN LIVER AND FORAGE MINERALS[a]

	Liver						
	Co	Cu	Fe	Mn	Mo	Se	Zn
Forage							
Ca	.192*	-.074	-.163	-.022	.080	.070	-.078
K	.107	.119	-.030	.028	.229*	-.037	-.092
Mg	.037	.274**	-.031	-.025	.172*	.171*	-.093
Na	.066	.144	.080	.032	.002	-.069	.009
P	-.142	-.078	-.020	-.042	-.109	-.031	-.184*
Co	.167+	.280**	.030	.134	-.040	-.006	.076
Cu	.156	.098	-.038	.018	.149	.050	-.146
Fe	-.126	-.037	.034	.035	-.043	-.120	-.122
Mn	-.181+	-.068	-.059	-.153	.032	.274**	-.035
Mo	.003	.073	.100	.020	.169+	.169+	.061
Se	-.128	-.047	-.044	-.057	.150	-.059	-.096
Zn	-.030	.106	-.089	-.018	.208+	.086	.093

[a] Error degrees of freedom = 99.

**P<.01.

*P<.05.

+P<.10.

TABLE 46. PARTIAL CORRELATION COEFFICIENTS BETWEEN BLOOD AND LIVER MINERALS[a]

	Blood[b]					
	Ca	Mg	P	Cu	Se	Zn
Liver						
Co	-.124[*]	-.064	.020	-.128[*]	-.058	-.051
Cu	.088	-.108	-.052	-.003	-.082	-.006
Fe	-.109	.176[*]	.082	.023	.074	-.175[*]
Mn	-.013	.088	.047	.144[+]	-.013	-.140[+]
Mo	-.012	.112	.032	.059	.072	-.071
Se	.064	.009	.165[*]	-.004	.092	-.005
Zn	.063	.063	-.027	.040	-.077	-.040

[a] Error degrees of freedom = 17.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[*] $P<.05$.

[+] $P<.10$.

TABLE 47. SOIL ORGANIC MATTER. pH, SOLUBLE SALTS AND MINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND DISTRICT[a]

		District					
Variable	Season	Gowa	Polmas	Enrekang	Sone	S.E.[b]	Significance[c,d]
OM[e], %	Rainy	5.0	5.7	4.8	4.1	1.1	S*
	Dry	7.0	7.7	6.7	4.8	1.1	
pH	Rainy	5.7	5.1	5.8	6.7	.37	
	Dry	5.9	6.3	5.7	8.1	.37	
SS[f], ppm	Rainy	382	624	540	815	180	S*
	Dry	322	434	385	592	180	
Al, ppm	Rainy	1252	1227	1202	1177	76	
	Dry	1232	1208	1389	1157	76	
Ca, ppm	Rainy	959	947	927	1427	68	S**.D**
	Dry	562	541	578	927	68	
K, ppm	Rainy	342	101	137	130	22	S**,D**
	Dry	311	82	116	118	22	
Mg. ppm	Rainy	185	393	439	440	38	D**.SD**
	Dry	184	471	199	460	35	
Na. ppm	Rainy	44	35	21	29	4.3	D**
	Dry	30	24	19	33	4.3	
P. ppm	Rainy	13	16	22	23	3.9	S*,D*
	Dry	12	15	21	22	3.9	

TABLE 47. CONTINUED

Variable	Season	District Gowa	 Polmas	 Enrekang	 Bone	S.E.	Significance
Cu, ppm	Rainy	3.1	.3	2.2	.5	.43	D^{**}, SD^{**}
	Dry	1.4	.9	1.8	2.1	.43	
Fe, ppm	Rainy	86.1	9.7	45.7	33.2	14.3	D^{**}
	Dry	114.4	6.3	49.3	61.3	14.3	
Mn, ppm	Rainy	9.1	21.8	99.4	37.2	14.3	D^{**}
	Dry	38.3	17.3	93.7	66.7	21.3	
Zn, ppm	Rainy	2.0	13.9	6.3	14.5	3.4	DS^{*}
	Dry	4.8	2.8	9.4	5.6	3.4	

[a] Means of 3 samples/district for each of the seasons.

[b] Standard error of means.

[c] S=season, D=district, SD=season x district interaction.

[d] See table 18 for details on S effect.

[e] Organic matter.

[f] Soluble salts.

$^{**}P<.01$, $^{*}P<.05$, $^{+}P<.10$.

TABLE 48. FORAGE MINERAL AND CRUDE PROTEIN CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND DISTRICT[a]

		District					
Variable	Season	Gowa	Polmas	Enrekang	Bone	S.E.[b]	Significance[c d]
Ca, %	Rainy	.35	.21	.49	.31	.06	D^{**},SD^{**}
	Dry	.45	.32	.36	.60	.06	
K, %	Rainy	2.53	1.20	1.29	1.63	.23	D^{**}
	Dry	2.34	1.26	1.04	1.24	.23	
Mg, %	Rainy	.24	.21	.20	.41	.03	D^{**},SD^{+}
	Dry	.22	.26	.27	.35	.03	
Na, %	Rainy	.07	.03	.07	.10	.02	D^{*}
	Dry	.09	.04	.06	.07	.02	
P, %	Rainy	.22	.19	.33	.18	.03	D^{**},SD^{*}
	Dry	.19	.30	.27	.20	.03	
Co, ppm	Rainy	.20	.36	.65	.33	.09	D^{**}
	Dry	.23	.34	.63	.32	.09	
Cu, ppm	Rainy	7.6	4.7	17.8	13.8	1.1	D^{**},SD^{**}
	Dry	8.2	6.1	8.2	12.0	1.1	
Fe, ppm	Rainy	868	262	209	436	99	S^{*},D^{**}
	Dry	1211	500	309	829	99	
Mn, ppm	Rainy	66	43	41	233	19	D^{**},SD^{**}
	Dry	112	72	31	161	19	

TABLE 48. CONTINUED

		District					
Variable	Season	Gowa	Polmas	Enrekang	Bone	S.E.	Significance
Mo, ppm	Rainy	.79	.60	.36	.76	.09	S[*],D[*]
	Dry	.36	.25	.28	.40	.05	
Se, ppm	Rainy	.06	.41	.40	.17	.02	D[**],SD[**]
	Dry	.08	.02	.74	.12	.02	
Zn, ppm	Rainy	27	38	29	47	5	D[*]
	Dry	23	28	42	36	5	
CP[e], %	Rainy	10.4	8.9	8.8	9.6	.99	S[*]
	Dry	8.0	5.9	8.2	8.3	.99	

[a] Means of 6 samples/district (3 samples/district for CP) for each of the seasons.

[b] Standard error of means.

[c] S=season, D=district, SD=season x district interaction.

[d] See table 18 for details on S effect

[e] Crude protein.

[**] P<.01.

[*] P<.05.

[+] P<.10.

TABLE 49 BLOOD MINERAL CONCENTRATIONS AS RELATED TO SEASON, DISTRICT AND ANIMAL SPECIES[a]

		District								
		Gowa		Polmas		Enrekang		Bone		
Variable[b]	Season	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Significance[c,d]
Ca, mg/dl	Rainy	8.3 (.13)	8.3 (.11)	8.9 (.13)	8.2 (.12)	8.3 (.13)	8.2 (.12)	8.4 (.13)	8.2 (.10)	S^{**}, D^{**}, DA^{**}
	Dry	8.5 (.13)	8.5 (.10)	9.1 (.13)	8.9 (.10)	8.7 (.13)	8.7 (.12)	8.7 (.13)	8.6 (.09)	
Mg, mg/dl	Rainy	2.3 (.08)	2.3 (.07)	2.2 (.08)	2.3 (.08)	2.2 (.08)	2.1 (.08)	2.6 (.08)	2.6 (.06)	D^{**}, SD^{**}
	Dry	2.7 (.08)	2.7 (.06)	2.4 (.08)	2.6 (.06)	2.4 (.08)	2.4 (.07)	2.6 (.08)	2.5 (.05)	
P, mg/dl	Rainy	7.6 (.68)	7.1 (.55)	5.9 (.68)	6.3 (.62)	6.1 (.68)	5.8 (.62)	2.7 (.68)	2.3 (.49)	D^{**}, SD^{**}
	Dry	5.9 (.68)	5.0 (.49)	3.9 (.68)	4.0 (.52)	5.6 (.68)	5.9 (.55)	5.2 (.68)	5.1 (.45)	
Cu, µg/ml	Rainy	.57 (.04)	.86 (.04)	.82 (.04)	.69 (.04)	.72 (.04)	.82 (.04)	.98 (.04)	1.06 (.03)	D^{**}, SD^{**}, DA^{**}, SDA^{*}
	Dry	.57 (.04)	.66 (.01)	.84 (.04)	.77 (.03)	.64 (.04)	.67 (.04)	.58 (.04)	.69 (.03)	
Se, µg/ml	Rainy	.11 (.01)	.01 (.01)	.15 (.01)	.07 (.01)	.13 (.01)	.04 (.01)	.07 (.01)	.08 (.01)	D^{**}, A^{*}, SD^{**}, DA^{**}, SDA^{**}
	Dry	.03 (.01)	.02 (.01)	.12 (.01)	.05 (.01)	.10 (.01)	.03 (.01)	.12 (.01)	.13 (.01)	

TABLE 49. CONTINUED

		District								
		Gowa		Polmas		Enrekang		Bone		
Variable	Season	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Significance
Zn, µg/ml	Rainy	.80 (.04)	.86 (.04)	1.22 (.04)	1.02 (.04)	1.03 (.04)	1.05 (.04)	.86 (.04)	.94 (.03)	S*,D**,SD**, SDA+
	Dry	.66 (.04)	.63 (.03)	.65 (.04)	.58 (.03)	.86 (.04)	.78 (.04)	.81 (.04)	.64 (.03)	

[a] Least squares means and standard error (in parentheses) of 10 cattle samples/district/season, and the following number of buffalo samples: Gowa, 15 and 19, Polmas, 12 and 17; Enrekang, 12 and 15; Bone, 19 and 23; for the rainy and dry seasons, respectively.

[b] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[c] S=season, D=district, A=animal species, SD=season x district interaction, DA=district x animal species interaction, SDA=season x district x animal species interaction

[d] See table 20 for details on S and A effects.

** P<.01.

* P<.05.

+ P<.10.

TABLE 58. BONE MINERAL CONCENTRATIONS (DRY, FAT-FREE BASIS) AND SPECIFIC GRAVITY AS RELATED TO SEASON, DISTRICT AND ANIMAL SPECIES[a]

		District								
		Gowa		Polmas		Enrekang		Bone		
Variable	Season	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Significance[b c]
Ca, %	Rainy	22.4 (.48)	22.7 (.39)	22.6 (.48)	22.7 (.44)	22.6 (.48)	22.4 (.44)	23.3 (.48)	23.4 (.35)	SD**
	Dry	23.7 (.48)	23.0 (.35)	23.3 (.48)	23.3 (.37)	24.0 (.48)	23.7 (.39)	22.4 (.48)	22.7 (.32)	
Mg, %	Rainy	.49 (.02)	.50 (.02)	.49 (.02)	.47 (.02)	.51 (.02)	.48 (.02)	.39 (.02)	.42 (.01)	SD**
	Dry	.41 (.02)	.39 (.01)	.39 (.02)	.42 (.01)	.39 (.02)	.40 (.02)	.49 (.02)	.40 (.01)	
P, %	Rainy	10.2 (.31)	10.1 (.22)	10.4 (.31)	10.3 (.24)	9.7 (.31)	10.2 (.25)	9.0 (.31)	10.3 (.20)	
	Dry	10.2 (.31)	10.1 (.22)	9.9 (.31)	10.2 (.24)	10.0 (.31)	10.4 (.25)	10.4 (.31)	10.6 (.20)	
Ash, %	Rainy	61.6 (1.24)	61.9 (1.02)	62.4 (1.24)	62.9 (1.14)	60.2 (1.24)	61.0 (1.14)	65.1 (1.24)	64.9 (.90)	SD**
	Dry	65.5 (1.24)	64.9 (.90)	65.1 (1.24)	62.0 (.95)	65.1 (1.24)	65.5 (1.02)	61.7 (1.24)	63.4 (.82)	

TABLE 58. CONTINUED

		District								
		Gowa		Polmas		Enrekang		Bone		
Variable	Season	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Significance[b,c]
SG[d], g/cm^3	Rainy	1.64 (.05)	1,66 (,04)	1.89 (.05)	1.73 (.04)	1.87 (.05)	1.65 (.04)	1.91 (.05)	1.82 (,03)	D**,SD**,SA*
	Dry	1.86 (.05)	1.89 (,03)	1.93 (.05)	1.90 (,03)	1.84 (.05)	1.98 (.04)	1,69 (.05)	1,74 (,03)	

[a] Least squares means and standard error (in parentheses) of 10 cattle samples/district/season, and the following number of buffalo samples: Gowa, 15 and 19, Polmas, 12 and 17, Enrekang, 12 and 15; Bone, 19 and 23; for the rainy and dry seasons, respectively.

[b] D=district, SD=season x district interaction, SA=season x animal species interaction

[c] See table 21 for details on SA effect.

[d] Specific gravity.

**P<,01.

*P<.10

TABLE 51. LIVER MINERAL CONCENTRATIONS AS RELATED TO SEASON, DISTRICT AND ANIMAL SPECIES[a]

		District								
		Gowa		Polmas		Enrekang		Bone		
Variable	Season	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Significance[b c]
Co, ppm	Rainy	.52	.54	.50	.52	.40	.50	.41	.56	A^*
		(.04)	(.03)	(.04)	(.04)	(.04)	(.04)	(.04)	(.03)	
	Dry	.46	.61	.45	.48	.50	.52	.51	.61	
		(.04)	(.03)	(.04)	(.03)	(.04)	(.03)	(.04)	(.03)	
Cu, ppm	Rainy	77	128	144	177	144	193	166	187	S^*,D^{**},A^*,SD^*, DA^*
		(16)	(13)	(16)	(14)	(16)	(14)	(16)	(11)	
	Dry	32	136	128	193	108	146	103	128	
		(16)	(11)	(16)	(12)	(16)	(13)	(16)	(10)	
Fe, ppm	Rainy	350	390	241	258	262	274	269	402	S^*,D^{**},DA^*
		(41)	(33)	(41)	(37)	(41)	(37)	(41)	(29)	
	Dry	376	421	270	303	252	303	346	481	
		(41)	(29)	(41)	(31)	(41)	(33)	(41)	(27)	
Mn, ppm	Rainy	9.3	9.6	6.2	6.4	7.5	7.3	13.0	11.8	D^{**},SD^{**}
		(.82)	(.67)	(.82)	(.75)	(.82)	(.75)	(.82)	(.60)	
	Dry	15.0	15.0	8.3	8.8	8.6	8.8	12.1	11.9	
		(.82)	(.60)	(.82)	(.63)	(.82)	(.67)	(.82)	(.54)	
Mo, ppm	Rainy	3.2	3.4	2.6	2.6	3.0	3.0	3.0	3.3	D^{**},SD^{**}
		(.26)	(.21)	(.26)	(.23)	(.26)	(.23)	(.26)	(.19)	
	Dry	3.2	3.1	3.0	2.9	3.2	3.4	3.7	4.1	
		(.26)	(.19)	(.26)	(.20)	(.26)	(.21)	(.26)	(.17)	

TABLE 51. CONTINUED

		District								
		Gowa		Polmas		Enrekang		Bone		
Variable	Season	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Cattle	Buffalo	Significance
Se, ppm	Rainy	.39 (.10)	.30 (.06)	.67 (.10)	.44 (.09)	.50 (.10)	.29 (.09)	1.16 (.16)	1.61 (.07)	D**,A*
	Dry	.19 (.10)	.16 (.07)	.69 (.10)	.46 (.06)	.57 (.10)	.36 (.06)	1.12 (.10)	.79 (.07)	
Zn, ppm	Rainy	109 (6.0)	117 (4.9)	109 (6.0)	105 (5.5)	109 (6.0)	108 (5.5)	128 (6.6)	124 (4.4)	S*,D**
	Dry	99 (6.0)	109 (4.4)	97 (6.0)	102 (4.6)	100 (6.0)	106 (4.9)	111 (6.0)	105 (4.6)	

[a] Least squares means and standard error (in parentheses) of 10 cattle samples/district/season, and the following number of buffalo samples: Gowa, 15 and 19, Polmas, 12 and 17; Enrekang, 12 and 15, Bone, 19 and 23, for the rainy and dry seasons, respectively.

[b] S=season, D=district, A=animal species, SD=season x district interaction, DA=district x animal species interaction.

[c] See table 22 for details on S and A effects.

[**] P<.01.

[*] P<.05.

[+] P<.10.

TABLE 52. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR SOIL VARIABLES (10 DISTRICTS)

	Source[a]					
Variable	S[b]	R[c]	SR[b]	D(R)	SD(R)	E
df[d]	1	2	2	7	7	40
OM[e]	27.702	23.377	3.650	6.872	.186	4.746
pH	.783	.155	.918	.238	.651	.420
BS[f]	374928	185273	27364	135259	2168	88183
Al	15.048	17674	8541	15498	8523	9305
Ca	2353863	89287	61.111	129922	3869	13628
K	9216	563.812	28886	895.448		3242
Mg	4102	102966	9088	35442	19204	3945
Na	2874	1118	145.264	186.248	208.851	78.983
P	4.105	583.443	005	54.282	1.177	29.182
Ca	.072	13.535	2.488	7.132	1.585	1.179
Fe	2869	22960	862.832	1890	1008	820.819
Mn	9.804	20028	2448	8022	895.981	2092

TABLE 52. CONTINUED

		Source					
Variable		S	R	SR	D(R)	SD(R)	E
	df	1	2	2	7	7	40
Zn		2.539	63.095	16.223	35.692	47.573	17.699

[a] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, E=error

[b] Tested using expected mean squares for SD(R) as the error term.

[c] Tested using expected mean squares for D(R) as the error term

[d] Degrees of freedom.

[e] Organic matter.

[f] Soluble salts.

TABLE 53. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR FORAGE VARIABLES (10 DISTRICTS)

Variable	Source^a					
	S^b	R^c	SR^b	D(R)	SD(R)	E
df^d	1	2	2	7	7	100
Ca	.002	.024	.130	.181	.125	.022
K	2.475	7.485	.001	1.499	.768	.353
Mg	.004	.066	.026	.028	.005	.004
Na	.015	.027	.002	.006	.006	.002
P	.001	.097	.002	.027	.013	.007
Co	.0001	.1343	.0063	.2279	.0001	.0358
Cu	561.028	1070	54.035	1053	141.079	49.379
Fe	741812	591233	335043	1157201	383360	66389
Mn	2419	73493	499.797	35563	43007	1921
Mo	4.078	16.535	332	3.035	.684	.416
Se	.588	1.661	206	.388	.221	.015
Zn	408.404	2336	542.210	933.009	415.815	158.870

TABLE 53. CONTINUED

	Source					
Variable	S	R	SR	D(R)	SD(R)	E
df	1	2	2	7	7	40
CP[e]	26.655	.637	.247	6.370	2.188	2.253

[a] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, E=error.

[b] Tested using expected mean squares for SD(R) as the error term.

[c] Tested using expected mean squares for D(R) as the error term.

[d] Degrees of freedom.

[e] Crude protein, the degrees of freedom for E is 40.

TABLE 54. ANALYSIS OF VARIANCE--TYPE III MEANS SQUARES FOR CATTLE BLOOD VARIABLES (10 DISTRICTS)

Variable[a]		Source[b]					
		S^c	R^d	SR^c	D(R)	SD(R)	E
	df[e]	1	2	2	7	7	180
Ca		.365	.380	.377	.636	.565	.165
Mg		1.805	.609	1.090	.161	.304	.062
P		3.026	22.771	6.557	9.460	19.836	.800
Cu		.069	.431	.015	.072	.121	.020
Se		.070	.040	.007	.007	.007	.001
Zn		3.274	.810	.033	.301	.183	.020

[a] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[b] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, E=error.

[c] Tested using expected mean squares for SD(R) as the error term.

[d] Tested using expected mean squares for D(R) as the error term.

[e] Degrees of freedom.

TABLE 55. ANALYSIS OF VARIANCE—TYPE III MEAN SQUARES FOR CATTLE BONE VARIABLES (10 DISTRICTS)

		Source[a]				
Variable	S[b]	R[c]	SR[b]	D(R)	SD(R)	E
df[d]	1	2	2	7	7	180
Ca	4.845	.316	3.244	1.398	4.196	2.237
Mg	.055	.001	.055	.001	.376	.004
P	.061	.156	.090	.156	1.725	.690
Ash	68.257	.635	31.599	4.383	45.787	7.618
SG[e]	.005	.241	.157	.024	.101	.017

[a] S=season, R=region, SR=season x region interaction, D(R)=district within region, SD(R)=season x district within region interaction, E=error.

[b] Tested using expected mean squares for SD(R) as the error term.

[c] Tested using expected mean squares for D(R) as the error term.

[d] Degrees of freedom.

[e] Specific gravity.

TABLE 56. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE LIVER VARIABLES (10 DISTRICTS)

Variable		Source[a]					
		S[b]	R[c]	SR[b]	D(R)	SD(R)	E
	df[d]	1	2	2	7	7	180
Co		.256	.101	.027	.051	.041	.016
Cu		15664	70917	3819	5791	4103	402.351
Fe		62405	131790	12779	49532	18104	9874
Mn		539.529	375.026	39.923	27.960	37.181	6.516
Mo		2.744	16.605	.369	3.902	.748	.646
Se		.079	9.303	.056	.195	.123	.063
Zn		1256	1505	116.786	1901	806.133	379.808

[a] S=season, R=region, SR=season x region interaction, O(R)=district within region, SO(R)=season x district within region interaction, E=error

[b] Tested using expected mean squares for SD(R) as the error term.

[c] Tested using expected mean squares for O(R) as the error term.

[d] Degrees of freedom.

TABLE 57. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR SOIL VARIABLES (4 DISTRICTS)

	Source[a]			
Variable	S[b]	D	SD	E
df[c]	1	3	3	16
OM[d]	17.002	5.145	.645	3.744
pH	.202	.554	.865	.421
SS[e]	147580	129788	7439	97162
Al	6048	17126	16000	17242
Ca	1021763	270496	6016	13980
K	2795	69221	76.375	1454
Mg	7633	90304	25498	4437
Na	187.042	303.597	106.153	54.792
P	2.802	133.036	.157	45.008
Cu	.002	3.192	3.121	.556
Fe	1199	8604	408.231	616.215
Mn	878.460	7544	594.394	1367
Zn	73.850	48.733	84.72	734.135

[a] S=season, D=district, SD=season x district interaction, E=error.

[b] Tested using expected mean squares for SD as the error term.

[c] Degrees of freedom.

[d] Organic matter.

[e] Soluble salts.

TABLE 58. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR FORAGE VARIABLES (4 DISTRICTS)

	Source[a]			
Variable	S[b]	D	SD	E
df[c]	1	3	3	40
Ca	.105	.066	.094	.022
K	.456	4.172	.106	.322
Mg	.001	.066	011	.004
Na	.0002	.0065	.0016	.005
P	.001	.027	.016	.005
Co	.0003	.4030	.0017	.0437
Cu	42.001	139.017	93.470	7.229
Fe	664302	1425655	50369	56475
Mn	12.710	61410	6355	2066
Mo	1.107	.190	.071	.051
Se	.004	.591	.269	.002
Zn	114.392	535.667	336.969	160.667
CP[d]	25.634	4.213	.942	2.936

[a] S=season, D=district, SD=season x district interaction, E=error.

[b] Tested using expected mean squares for SD as the error term.

[c] Degrees of freedom.

[d] Crude protein, the degrees of freedom for E is 16.

TABLE 39. ANALYSIS OF VARIANCE—TYPE III MEAN SQUARES FOR CATTLE AND BUFFALO BLOOD VARIABLES (4 DISTRICTS)

Variable[a]		Source[b]						
	S[c]	D	SD	A[d]	SA[e]	DA	SDA	E
df[f]	1	3	3	1	1	3	3	196
Ca	6.612	1.361	.188	.712	.135	.458	.140	.173
Mg	1.822	.715	.450	.053	.002	.056	.024	.068
P	7.440	64.861	63.178	1.916	.011	1.661	.698	4.568
Cu	.913	.269	.414	180	.025	.170	.413	019
Se	.005	.030	.024	.133	.008	.021	.003	.001
Zn	3.320	.259	.198	.070	.004	.015	.130	.019

[a] Plasma for Ca and P, and serum for Mg, Cu, Se and Zn.

[b] S=season, D=district, SD=season x district interaction, A=animal species, SA=season x animal species interaction, DA=district x animal species interaction, SDA=season x district x animal species interaction, E=error.

[c] Tested using expected mean squares for SD as the error term.

[d] Tested using expected mean squares for DA as the error term.

[e] Tested using expected mean squares for SDA as the error term.

[f] Degrees of freedom.

TABLE 60. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE AND BUFFALO BONE VARIABLES (4 DISTRICTS)

Variable		Source[a]							
		S[b]	D	SD	A[c]	SA[d]	DA	SDA	E
	df[e]	1	3	3	1	1	3	3	196
Ca		16.197	.539	11.745	.031	.001	.472	.158	2.299
Mg		.1136	.0004	.0983	.0001	.0003	.0009	.0061	.0036
P		.418	104	1.460	.125	1.293	.130	1.131	.944
Ash		125.583	5.240	119.449	.122	8.458	12.006	15.789	15.497
SG[f]		.236	.084	.321	.088	.235	.037	.035	.021

[a] S=season, D=district, SD=season x district interaction, A=animal species, SA=season x animal species interaction, DA=district x animal species interaction, SDA=season x district x animal species interaction, E=error.

[b] Tested using expected mean squares for SD as the error term.

[c] Tested using expected mean squares for DA as the error term.

[d] Tested using expected mean squares for SDA as the error term.

[e] Degrees of freedom.

[f] Specific gravity.

TABLE 61. ANALYSIS OF VARIANCE--TYPE III MEAN SQUARES FOR CATTLE AND BUFFALO LIVER VARIABLES (4 DISTRICTS)

Variable		Source[a]						
	S[b]	D	SD	A[c]	SA[d]	DA	SDA	E
df[e]	1	3	3	1	1	3	3	196
Co	.025	.029	.035	.276	.001	.021	.027	.018
Cu	66168	36438	6441	85424	560.007	8673	2871	2405
Fe	75299	197622	10605	158867	4073	35112	890.268	16507
Mn	231.452	331.269	80.524	.249	1.407	2.547	1.328	6.806
Mo	4.849	4.557	1.765	.499	.056	.441	.113	.681
Sn	.125	5.551	.168	1.698	.005	.105	.032	.099
Zn	4580	1906	380.962	100.165	196.138	506.513	108.937	362.707

[a] S=season, D=district, SD=season x district interaction, A=animal species, SA=season x animal species interaction, DA=district x animal species interaction, SDA=season x district x animal species interaction, E=error.

[b] Tested using expected mean squares for SD as the error term.

[c] Tested using expected mean squares for DA as the error term.

[d] Tested using expected mean squares for SDA as the error term.

[e] Degrees of freedom.

APPENDIX B

RAW DATA

SOIL DATA CODES

OBS = Observation number (1-60).

SEA = Season:
- 1. Rainy.
- 2. Dry.

RGN = Region:
- 1. Western.
- 2. Central.
- 3. Eastern.

DST = District:
- 1. Jeneponto.
- 2. Gowa.
- 3. Barru.
- 4. Polmas.
- 5. Enrekang.
- 6. Sidrap.
- 7. Wajo.
- 8. Soppeng.
- 9. Bone.
- 10. Bulukumba.

SPL = Sample number (1-3).

SO_OM = Soil organic matter, % dry basis.
SO_PH = Soil pH.
SO_SS = Soil soluble salts, ppm dry basis.
SO_AL = Soil aluminum, ppm dry basis.
SO_CA = Soil calcium, ppm dry basis.
SO_K = Soil potassium, ppm dry basis.
SO_MG = Soil magnesium, ppm dry basis.
SO_NA = Soil sodium, ppm dry basis.
SO_P = Soil phosphorus, ppm dry basis.
SO_FE = Soil iron, ppm dry basis.
SO_CU = Soil copper, ppm dry basis.
SO_MN = Soil manganese, ppm dry basis.
SO_ZN = Soil zinc, ppm dry basis.

SOIL DATA

OBS	SRA	BGB	OST	SPL	SO_OM	SO_PH	SO_SV	SO_AL	SO_CA	SO_K	SO_MG	SO_NA	SO_P	SO_CU	SO_FE	SO_MN	SO_ZN
1	1	1	1	1	3.9	6.1	900	1252	900	552	200	36	7.6	2.6	116.0	13.6	1.8
2	1	1	1	2	4.1	5.8	446	1120	880	324	208	36	6.8	2.7	108.0	23.2	3.0
3	1	1	1	3	2.9	5.4	221	1116	1150	340	512	56	6.2	0.9	72.0	15.2	7.6
4	1	1	2	1	5.0	5.1	238	1245	1060	880	184	40	12.8	1.0	88.0	11.6	3.6
5	1	1	2	2	4.5	6.4	218	1298	980	341	190	52	15.6	4.0	95.2	8.0	1.1
6	1	1	2	3	5.5	5.6	899	1245	856	325	190	40	11.6	4.4	95.2	7.6	1.2
7	1	1	3	1	5.9	6.6	446	1225	880	288	198	44	9.4	0.6	98.2	11.2	4.8
8	1	1	3	2	5.8	5.3	451	1206	1060	252	200	32	8.8	0.6	75.2	17.2	6.0
9	1	1	3	3	5.1	6.3	228	1215	1020	188	281	28	2.2	0.5	88.0	12.8	4.4
10	1	2	4	1	5.2	5.1	1143	1200	1060	96	272	40	16.8	0.2	12.0	3.5	28.0
11	1	2	4	2	4.8	4.0	249	1280	980	132	436	36	15.2	0.3	14.8	52.0	10.1
12	1	2	4	3	9.1	8.2	880	1212	820	76	452	28	14.8	0.2	2.4	10.0	5.6
13	1	2	5	1	5.5	4.9	983	1201	940	132	444	20	28.0	2.1	40.0	36.0	4.5
14	1	2	5	2	5.2	6.1	286	1198	720	76	880	22	28.0	2.1	35.2	98.1	4.0
15	1	2	5	3	5.2	6.5	888	1268	1120	204	512	21	18.0	2.3	88.0	198.2	10.5
16	1	2	6	1	4.8	2.0	291	1255	298	112	108	28	20.0	2.8	48.0	228.0	4.8
17	1	2	6	2	2.9	6.9	1303	1065	880	116	176	24	21.6	2.3	31.4	56.0	4.0
18	1	2	6	3	12.9	3.6	1012	1164	1060	252	272	28	15.8	2.9	92.0	228.0	11.2
19	1	3	7	1	6.0	6.5	600	1185	1080	256	524	40	28.6	3.5	62.0	44.0	3.3
20	1	3	7	2	2.2	4.6	438	1119	784	80	198	34	16.0	1.6	5.6	16.0	1.1
21	1	3	7	3	5.6	6.0	415	1108	1000	280	284	80	10.0	3.4	16.0	128.0	1.1
22	1	3	8	1	7.1	5.5	480	1122	880	176	281	36	22.4	2.8	80.0	44.0	5.6
23	1	3	8	2	5.1	5.9	997	1237	720	44	280	44	12.0	2.9	78.0	28.0	2.9
24	1	3	8	3	2.5	6.6	864	1132	892	64	880	90	23.2	2.4	52.0	41.0	5.9
25	1	3	9	1	6.3	6.3	693	1199	1080	188	312	32	13.1	0.4	5.2	10.0	25.2
26	1	3	9	2	3.3	6.9	970	1209	1440	110	412	16	36.6	0.3	10.4	5.6	2.2
27	1	3	9	3	2.6	6.8	781	1158	1080	121	596	38	21.0	0.8	98.0	96.0	16.0
28	1	3	10	1	1.8	3.5	880	1288	1000	480	576	80	16.4	2.9	28.0	198.0	4.4
29	1	3	10	2	2.3	6.2	258	1156	920	500	530	80	19.2	6.4	5.6	18.2	5.3
30	1	3	10	3	4.8	5.6	682	1190	1010	280	288	39	14.2	4.0	4.8	28.0	5.0
31	2	1	1	1	3.4	3.4	815	1236	510	342	296	28	6.8	2.2	129.2	27.2	5.1
32	2	1	1	2	6.9	2.3	347	1108	860	382	302	18	6.2	2.6	122.8	72.0	4.4
33	2	1	1	3	2.4	6.8	228	1008	758	304	330	20	8.0	1.6	108.4	52.8	3.0
34	2	1	2	1	4.5	4.4	228	1224	640	888	204	38	11.6	1.9	125.2	36.8	4.0
35	2	1	2	2	6.5	5.7	210	1247	986	314	168	32	14.8	0.9	86.6	44.0	4.4
36	2	1	2	3	8.0	5.7	529	1226	456	298	130	20	11.0	1.5	118.4	34.0	3.9
37	2	1	3	1	5.4	6.8	526	1204	590	260	196	22	9.6	0.6	96.8	18.4	4.0
38	2	1	3	2	5.8	6.3	350	1187	880	222	210	18	7.8	0.3	111.6	45.0	12.0
39	2	1	3	3	2.6	6.2	198	1196	628	176	278	14	7.2	0.3	94.8	18.8	8.6
40	2	2	4	1	4.2	6.1	888	1191	624	58	448	24	14.0	1.2	8.0	16.0	3.4
41	2	2	4	2	4.8	6.1	160	1259	520	112	462	14	12.0	0.2	0.4	5.6	1.8
42	2	2	4	3	10.1	6.7	264	1183	480	76	512	32	14.4	1.4	10.4	32.4	3.4
43	2	2	5	1	8.5	6.2	756	1101	554	92	110	18	26.4	1.2	46.8	128.0	6.0
44	2	2	5	2	2.2	5.7	299	1177	420	28	128	18	20.0	1.8	49.0	104.0	9.6
45	2	2	5	3	4.5	3.3	128	1600	768	138	296	26	18.8	1.8	53.0	49.0	10.5
46	2	2	6	1	2.8	5.2	96	1214	590	128	394	12	22.2	1.9	34.8	42.4	8.0
47	2	2	6	2	4.9	3.3	880	1088	420	96	888	14	19.4	1.8	52.0	124.0	0.2
48	2	2	6	3	11.2	6.0	703	1145	648	190	290	10	15.6	1.0	56.0	210.0	11.2
49	2	3	7	1	6.8	2.2	424	1146	780	198	298	26	26.8	1.9	4.0	56.0	1.9
50	2	3	7	2	2.9	5.8	260	1098	514	38	328	16	14.6	3.1	6.0	19.0	1.9
51	2	3	7	3	5.2	6.1	230	1087	600	232	514	28	18.2	2.5	2.6	21.2	2.8
52	2	3	8	1	7.9	5.9	268	1101	448	156	488	24	22.6	2.0	26.0	52.0	12.4
53	2	3	8	2	3.0	6.5	789	1218	529	98	412	28	12.8	7.6	100.0	88.0	2.8
54	2	3	8	3	8.1	5.8	868	1115	496	76	512	18	28.2	3.7	25.6	25.2	4.4
55	2	3	9	1	7.3	6.8	488	1137	990	146	880	34	10.8	2.5	128.6	190.0	8.6
56	2	3	9	2	4.8	5.9	880	1184	916	90	510	38	34.1	1.6	16.0	56.0	5.7
57	2	3	9	3	5.2	5.5	596	1150	688	112	590	28	22.8	8.8	98.0	44.0	4.8
58	2	3	10	1	2.6	3.3	188	1267	620	288	688	36	14.4	4.4	19.2	19.2	2.3
59	2	3	10	2	2.0	4.6	136	1137	540	298	680	32	16.8	2.2	96.0	76.8	2.2
60	2	3	10	3	4.4	5.2	480	1172	880	252	312	29	12.6	3.8	128.0	90.4	2.2

FORAGE DATA CODES

OBS = Observation number (1-120)

SEA = Season: 1. Rainy.
2. Dry.

RGN = Region: 1. Western.
2. Central.
3. Eastern.

DST = District: 1. Jeneponto.
2. Gowa.
3. Barru.
4. Polmas.
5. Enrekang.
6. Sidrap.
7. Wajo.
8. Soppeng.
9. Bone.
10. Bulukumba.

SPL = Sample number (1-6).

FO_CA = Forage calcium, % dry basis.
FO_K = Forage potassium, % dry basis.
FO_MG = Forage magnesium, % dry basis.
FO_NA = Forage sodium, % dry basis.
FO_P = Forage phosphorus, % dry basis.
FO_FE = Forage iron, ppm dry basis.
FO_CO = Forage cobalt, ppm dry basis.
FO_CU = Forage copper, ppm dry basis.
FO_MN = Forage manganese, ppm dry basis.
FO_MO = Forage molybdenum, ppm dry basis.
FO_SE = Forage selenium, ppm dry basis.
FO_ZN = Forage zinc, ppm dry basis.
FO_CP = Forage crude protein, % dry basis.

FORAGE DATA

OBS	SEA	RUN	DST	SPL	FO_CA	FO_K	FO_MG	FO_NA	FO_P	FO_CO	FO_CU	FO_FE	FO_MN	FO_MO	FO_SE	FO_ZN	FO_CP
1	1	1	1	1	0.78	1.92	0.10	0.07	0.14	0.21	2.8	783	117.1	0.40	0.03	15.4	7.7
2	1	1	1	2	0.96	1.79	0.10	0.11	0.15	0.41	7.4	760	163.0	0.55	0.07	21.2	7.8
3	1	1	1	3	0.28	1.98	0.10	0.26	0.15	0.38	3.7	226	150.4	0.55	0.16	27.3	6.5
4	1	1	1	4	0.33	1.67	0.17	0.27	0.14	0.29	5.2	195	141.0	0.54	0.06	29.8	
5	1	1	1	5	0.79	1.86	0.17	0.08	0.14	0.41	6.2	827	115.5	4.07	0.05	16.1	
6	1	1	1	6	0.30	1.57	0.17	0.25	0.16	0.16	4.7	245	146.0	0.57	0.08	29.6	
7	1	1	2	1	0.45	2.86	0.35	0.02	0.28	0.12	6.4	1004	72.4	1.43	0.07	26.7	10.1
8	1	1	2	2	0.41	2.98	0.12	0.03	0.25	0.08	5.6	1152	50.6	0.98	0.08	29.3	10.4
9	1	1	2	3	0.15	1.08	0.29	0.05	0.16	0.25	6.8	548	17.7	0.61	0.04	14.1	10.7
10	1	1	2	4	0.35	2.27	0.86	0.02	0.18	0.10	5.4	560	98.0	0.57	0.05	16.6	
11	1	1	2	5	0.15	3.88	0.27	0.14	0.23	0.08	11.7	1225	108.1	1.11	0.06	51.5	
12	1	1	2	6	0.41	5.29	0.10	0.11	0.22	0.16	7.4	716	61.0	0.54	0.35	29.5	
13	1	1	3	1	0.52	2.88	0.24	0.08	0.80	0.61	7.8	484	58.5	0.57	0.34	18.0	8.7
14	1	1	3	2	0.44	2.84	0.22	0.07	0.58	0.45	15.6	531	71.1	1.35	0.68	21.1	8.6
15	1	1	3	3	0.52	2.71	0.24	0.03	0.34	0.45	11.0	482	93.2	0.14	0.07	23.7	7.1
16	1	1	3	4	0.44	2.55	0.23	0.04	0.16	0.15	11.6	499	45.5	0.16	0.06	55.5	
17	1	1	3	5	0.22	3.41	0.22	0.30	0.22	0.43	32.8	368	110.0	0.16	0.08	27.4	
18	1	1	3	6	0.25	3.54	0.22	0.28	0.21	0.36	24.5	349	108.0	0.18	0.55	50.8	
19	1	2	4	1	0.21	1.34	0.20	0.13	0.24	0.15	5.2	250	46.3	0.66	0.36	49.5	8.1
20	1	2	4	2	0.23	1.27	0.21	0.08	0.23	0.23	6.6	244	45.5	0.86	0.40	45.1	8.6
21	1	2	4	3	0.06	1.36	0.17	0.02	0.19	0.16	7.4	301	34.4	0.47	0.40	51.1	4.6
22	1	2	4	4	0.25	1.36	0.17	0.03	0.19	0.44	6.9	407	38.5	0.52	0.39	36.6	
23	1	2	4	5	0.17	0.97	0.38	0.04	0.14	0.50	1.0	149	46.0	0.46	0.47	15.7	
24	1	2	4	6	0.13	0.64	0.25	0.02	0.16	0.98	1.1	132	46.5	0.38	0.43	10.7	
25	1	2	5	1	0.43	1.15	0.10	0.08	0.25	0.40	16.2	103	35.5	0.38	0.40	36.2	8.6
26	1	2	5	2	0.40	1.16	0.08	0.07	0.20	0.42	16.2	170	56.4	0.43	0.48	31.2	8.3
27	1	2	5	3	0.57	1.90	0.18	0.36	0.40	0.41	16.2	157	50.3	0.31	0.38	28.3	12.4
28	1	2	5	4	0.59	1.30	0.29	0.36	0.41	1.25	15.5	153	85.2	0.29	0.39	34.5	
29	1	2	5	5	0.57	1.08	0.21	0.05	0.41	0.61	16.5	421	40.2	0.36	0.39	68.4	
30	1	2	5	6	0.40	1.00	0.23	0.08	0.31	0.33	18.6	250	31.8	0.31	0.38	25.4	
31	1	2	6	1	0.40	1.04	0.24	0.06	0.27	0.21	16.6	1369	888.6	0.54	0.33	55.4	8.6
32	1	2	6	2	0.39	0.62	0.16	0.05	0.86	0.21	15.7	1150	233.5	0.60	0.32	41.6	6.0
33	1	2	6	3	0.34	5.77	0.18	0.11	0.21	0.41	80.7	658	98.4	0.13	0.32	26.1	6.4
34	1	2	6	4	0.45	5.98	0.21	0.13	0.20	0.36	36.3	867	115.1	0.18	0.32	26.2	
35	1	2	6	5	0.55	5.50	0.46	0.12	0.43	0.29	80.7	1377	154.3	0.29	0.40	49.7	
36	1	2	6	6	0.67	5.00	0.47	0.15	0.38	0.41	90.2	1399	163.6	0.08	0.39	77.6	
37	1	3	7	1	0.43	1.46	0.32	0.06	0.60	0.15	15.8	885	788.6	1.73	0.76	51.2	13.6
38	1	3	7	2	0.42	5.01	0.16	0.12	0.65	0.51	10.0	498	222.0	2.36	0.43	24.1	11.5
39	1	3	7	3	0.45	5.45	0.27	0.04	0.25	0.14	16.6	766	205.1	1.31	0.16	26.6	7.2
40	1	3	7	4	0.44	2.86	0.16	0.09	0.17	0.06	4.7	399	291.4	3.13	0.17	24.5	
41	1	3	7	5	0.51	1.08	0.27	0.29	0.39	0.75	23.3	467	154.4	8.47	0.17	48.4	
42	1	3	7	6	0.40	5.97	0.39	0.15	0.33	0.67	33.0	565	226.2	0.36	0.16	81.6	
43	1	3	8	1	0.33	0.44	0.52	0.05	0.17	0.09	14.4	340	68.2	1.88	0.34	35.7	6.7
44	1	3	8	2	0.38	0.34	0.46	0.04	0.21	0.36	14.4	516	79.1	2.01	0.29	33.8	7.5
45	1	3	8	3	0.40	5.20	0.29	0.05	0.27	0.86	12.4	954	79.4	1.60	0.56	32.6	10.2
46	1	3	8	4	0.45	2.40	0.31	0.08	0.38	0.08	15.6	888	88.6	1.71	0.57	38.5	
47	1	3	8	5	0.45	1.15	0.33	0.07	0.17	0.62	18.0	960	77.2	1.61	0.80	32.1	
48	1	3	8	6	0.41	1.29	0.27	0.04	0.16	0.37	15.4	960	76.1	1.69	0.39	38.2	
49	1	3	9	1	0.56	1.84	0.49	0.22	0.15	0.47	13.8	454	513.2	1.18	0.98	46.2	10.0
50	1	3	9	2	0.17	0.37	0.45	0.03	0.15	0.37	18.4	348	155.5	0.08	0.17	86.0	10.5
51	1	3	9	3	0.32	1.22	0.40	0.17	0.15	0.23	8.4	405	265.5	1.17	0.15	39.4	7.4
52	1	3	9	4	0.34	0.08	0.34	0.05	0.11	0.08	8.1	321	129.3	0.57	0.16	22.9	
53	1	3	9	5	0.52	3.33	0.57	0.98	0.55	0.55	20.4	515	261.3	0.73	0.16	70.6	
54	1	3	9	6	0.32	5.11	0.37	0.07	0.26	0.20	16.6	576	274.6	0.88	0.16	74.8	
55	1	3	10	1	0.51	0.95	0.22	0.05	0.16	0.35	8.0	593	112.6	2.65	0.32	24.5	6.6
56	1	3	10	2	0.40	1.15	0.25	0.04	0.15	0.29	7.3	372	116.7	2.84	0.29	42.5	7.1
57	1	3	10	3	0.45	5.08	0.38	0.05	0.40	0.43	4.5	707	84.7	3.98	1.23	48.4	10.1
58	1	3	10	4	0.40	5.08	0.38	0.06	0.33	0.16	8.8	757	93.1	5.22	0.60	44.4	
59	1	3	10	5	0.08	1.86	0.15	0.07	0.23	0.57	10.2	266	20.8	1.73	0.11	15.4	
60	1	3	10	6	0.14	1.63	0.16	0.01	0.80	0.42	10.7	258	25.8	1.32	0.18	14.3	

FORAGE DATA

OBS	YEA	ROP	CST	SPL	FO_CA	FO_K	FO_MG	FO_NA	FO_P	FO_CU	FO_CO	FO_FE	FO_MN	FO_MO	FO_SE	FO_ZN	FO_CP
61	2	1	1	1	0.70	1.34	0.18	0.16	0.12	0.09	0.0	1577	84.6	0.74	0.10	30.7	8.2
62	2	1	1	2	0.77	1.37	0.17	0.16	0.10	0.41	0.2	384	89.3	0.24	0.10	23.6	8.5
63	2	1	1	3	0.66	2.08	0.18	0.00	0.18	0.44	0.4	711	89.3	0.47	0.12	27.2	5.8
64	2	1	1	4	0.21	2.13	0.10	0.08	0.05	0.29	8.9	328	73.2	0.30	0.10	23.8	—
65	2	1	1	5	0.31	1.91	0.17	0.07	0.12	0.47	7.7	1253	94.0	0.10	0.11	43.2	
66	2	1	1	6	0.42	2.01	0.18	0.09	0.12	0.18	7.7	1092	73.2	0.15	0.11	37.7	
67	2	1	2	1	0.44	2.55	0.24	0.09	0.25	0.58	8.8	989	223.2	0.21	0.08	51.6	8.8
68	2	1	2	2	0.42	2.33	0.00	0.08	0.30	0.68	8.4	1258	238.2	0.33	0.08	57.7	8.2
69	2	1	2	3	0.45	2.30	0.23	0.10	0.11	0.51	7.5	1061	51.5	0.24	0.08	22.6	7.0
70	2	1	2	4	0.44	2.38	0.25	0.11	0.12	0.10	7.8	1325	41.5	0.27	0.38	15.9	—
71	2	1	2	5	0.50	2.24	0.23	0.09	0.16	0.84	8.1	1184	63.0	0.59	0.11	14.0	
72	2	1	2	6	0.47	2.12	0.21	0.09	0.18	0.18	9.5	1238	64.5	0.53	0.11	18.7	
73	2	1	3	1	0.26	2.05	0.22	0.09	0.20	0.07	8.7	660	38.8	0.15	0.12	31.0	8.2
74	2	1	3	2	0.26	2.11	0.22	0.07	0.22	0.45	7.1	642	29.5	0.21	0.11	36.4	8.1
75	2	1	3	3	0.13	2.20	0.23	0.08	0.18	0.51	6.5	603	31.0	0.24	0.10	29.8	7.5
76	2	1	3	4	0.12	2.35	0.23	0.00	0.19	0.15	7.2	400	29.9	0.21	0.09	51.2	
77	2	1	3	5	0.10	2.21	0.20	0.10	0.10	0.40	6.6	344	64.5	0.18	0.11	37.8	
78	2	1	3	6	0.14	2.29	0.29	0.12	0.15	0.38	8.0	425	72.8	0.36	0.10	42.0	
79	2	2	4	1	0.21	1.07	0.23	0.03	0.06	0.15	7.7	234	95.6	0.18	0.01	23.0	5.0
80	2	2	4	2	0.18	1.04	0.22	0.05	0.22	0.18	7.4	222	87.1	0.19	0.03	32.7	4.8
81	2	2	4	3	0.21	1.46	0.25	0.04	0.34	0.15	7.7	231	76.4	0.21	0.01	23.7	7.7
82	2	2	4	4	0.20	1.55	0.25	0.08	0.09	0.44	8.4	223	78.6	0.21	0.32	28.1	
83	2	2	4	5	0.55	1.22	0.50	0.06	0.35	0.48	8.7	1076	47.6	0.36	0.03	36.0	
84	2	2	4	6	0.55	1.23	0.30	0.04	0.37	0.66	8.6	1013	59.2	0.36	0.03	23.5	
85	2	2	5	1	0.08	0.80	0.28	0.03	0.23	0.36	7.0	447	29.0	0.38	0.00	35.0	7.2
86	2	2	5	2	0.39	0.80	0.26	0.05	0.21	0.42	8.4	474	33.4	0.32	0.06	41.4	7.0
87	2	2	5	3	0.33	1.30	0.23	0.07	0.28	0.37	8.5	310	24.2	0.24	0.69	33.4	10.4
88	2	2	5	4	0.34	0.80	0.23	0.07	0.08	1.09	10.0	263	29.0	0.27	0.86	46.0	
89	2	2	5	5	0.38	1.42	0.09	0.09	0.30	0.57	8.6	170	44.2	0.28	0.98	47.1	
90	2	2	5	6	0.35	1.09	0.20	0.07	0.31	0.83	7.0	170	33.9	0.08	0.65	43.5	
91	2	2	6	1	0.08	1.51	0.29	0.08	0.24	0.17	11.3	1025	107.1	0.33	0.06	98.9	8.2
92	2	2	6	2	0.52	1.35	0.09	0.03	0.22	0.21	13.1	882	172.5	0.26	0.05	74.4	6.1
93	2	2	6	3	0.28	1.75	0.27	0.03	0.30	0.37	36.7	360	76.8	0.23	0.62	90.3	8.8
94	2	2	6	4	0.27	1.74	0.08	0.03	0.22	0.38	34.4	396	86.5	0.23	0.08	90.8	
95	2	2	6	5	0.51	1.04	0.27	0.04	0.34	0.25	40.1	443	78.0	0.29	0.63	51.0	
96	2	2	6	6	0.31	1.11	0.29	0.09	0.28	0.41	51.2	608	92.5	0.22	0.80	46.3	
97	2	3	7	1	0.39	0.62	0.15	0.05	0.23	0.13	7.7	1066	98.8	0.84	0.77	52.8	8.3
98	2	3	7	2	0.33	0.66	0.15	0.08	0.23	0.21	8.3	783	76.5	0.84	0.70	23.8	8.0
99	2	3	7	3	0.59	0.08	0.00	0.04	0.23	0.12	8.5	807	112.8	0.67	0.71	45.8	8.2
100	2	3	7	4	0.41	0.00	0.27	0.09	0.08	0.69	8.7	728	106.3	0.78	0.86	57.1	
101	2	3	7	5	0.16	2.41	0.21	0.08	0.40	0.73	10.0	308	32.2	1.38	0.72	24.1	
102	2	3	7	6	0.19	5.24	0.27	0.05	0.09	0.87	10.3	430	45.0	1.84	0.71	40.7	
103	2	3	8	1	0.80	1.61	0.80	0.11	0.32	0.87	10.4	1320	418.2	2.38	0.72	33.6	8.5
104	2	3	8	2	0.90	1.01	0.38	0.13	0.34	0.38	6.0	1148	403.2	3.33	0.74	29.0	7.1
105	2	3	8	3	0.69	1.25	0.16	0.12	0.09	0.38	8.7	1493	200.0	0.01	0.74	24.7	8.7
106	2	3	8	4	0.59	1.40	0.17	0.19	0.18	0.98	8.3	1396	246.8	1.55	0.81	37.7	
107	2	3	8	5	0.91	1.15	0.23	0.08	0.23	0.86	11.8	1761	382.1	1.85	0.76	38.4	
108	2	3	8	6	0.93	0.92	0.21	0.11	0.16	0.37	11.0	1769	327.6	1.71	0.80	43.7	
109	2	3	9	1	0.46	0.79	0.18	0.39	0.09	0.45	7.7	582	115.1	0.27	0.11	24.7	8.4
110	2	3	9	2	0.40	0.80	0.10	0.35	0.09	0.37	8.5	235	120.8	0.18	0.12	34.1	8.8
111	2	3	9	3	0.64	1.57	0.43	0.09	0.29	0.21	16.8	1140	167.5	0.42	0.12	39.5	11.8
112	2	3	9	4	0.04	1.40	0.45	0.07	0.25	0.26	16.4	1241	158.2	0.48	0.11	36.0	
113	2	3	9	5	0.41	1.66	0.46	0.13	0.30	0.33	15.2	840	193.3	0.54	0.13	38.4	
114	2	3	9	6	0.36	1.05	0.30	0.04	0.10	0.89	13.4	637	213.8	0.28	0.10	42.7	
115	2	3	10	1	0.10	1.74	0.80	0.03	0.32	0.33	0.7	179	36.5	1.53	0.76	27.5	7.0
116	2	3	10	2	0.12	1.74	0.21	0.02	0.08	0.29	0.8	109	38.5	1.74	0.82	29.6	6.7
117	2	3	10	3	0.21	1.80	0.09	0.03	0.20	0.41	12.4	174	48.9	0.72	0.80	34.9	7.0
118	2	3	10	4	0.80	1.64	0.27	0.04	0.21	0.10	10.3	157	47.3	1.80	0.80	34.7	—
119	2	3	10	5	0.33	1.66	0.23	0.05	0.24	0.35	8.8	387	54.4	2.01	0.81	30.0	
120	2	3	10	6	0.34	2.26	0.27	0.07	0.08	0.42	8.4	405	38.1	2.45	0.82	31.7	.

BLOOD DATA CODES

OBS = Observation number (1-332).

SEA = Season:
- 1. Rainy.
- 2. Dry

RGN = Region:
- 1. Western.
- 2. Central
- 3. Eastern.

DST = District:
- 1. Jeneponto.
- 2. Gowa.
- 3. Barru.
- 4. Polmas.
- 5. Enrekang.
- 6. Sidrap.
- 7. Wajo.
- 8. Soppeng.
- 9. Bone.
- 10 Bulukumba.

SPC = Animal species:
- 1. Cattle.
- 2. Buffalo.

SPL = Sample number (1-23).

BP_CA = Blood plasma calcium, mg/dl.
BS_MG = Blood serum magnesium, mg/dl.
BP_P = Blood plasma phosphorus, mg/dl.
BS_CU = Blood serum copper, µg/ml.
BS_SE = Blood serum selenium, µg/ml.
BS_ZN = Blood serum zinc, µg/ml.

BLOOD DATA

OBS	SEX	RUN	DST	SPC	SFL	BP_CA	BP_MG	BP_P	BS_CU	BS_SE	BS_ZN
1	1	1	1	1	1	8.3	2.2	6.5	0.85	0.06	0.86
2	1	1	1	1	2	8.6	2.1	4.8	0.79	0.10	0.62
3	1	1	1	1	3	8.7	2.2	6.5	0.30	0.10	0.86
4	1	1	1	1	4	8.4	2.3	6.6	0.44	0.10	1.05
5	1	1	1	1	5	8.4	2.6	7.0	0.78	0.10	0.87
6	1	1	1	1	6	8.4	1.9	7.0	0.74	0.06	0.86
7	1	1	1	1	7	7.8	2.2	6.5	0.77	0.10	1.06
8	1	1	1	1	8	8.3	2.2	7.0	0.67	0.10	0.93
9	1	1	1	1	9	8.6	2.3	7.2	0.42	0.06	0.78
10	1	1	1	1	10	8.3	2.7	6.0	0.30	0.15	1.13
11	1	1	2	1	1	8.3	2.3	6.7	0.65	0.11	0.61
12	1	1	2	1	2	8.4	2.4	6.4	0.65	0.12	0.74
13	1	1	2	1	3	7.9	2.8	7.8	0.71	0.13	0.88
14	1	1	2	1	4	7.8	2.5	7.4	0.31	0.13	0.78
15	1	1	2	1	5	8.5	2.1	8.8	0.36	0.13	0.76
16	1	1	2	1	6	8.4	2.4	7.9	0.54	0.13	0.86
17	1	1	2	1	7	8.1	2.2	7.0	0.44	0.06	0.87
18	1	1	2	1	8	7.6	2.2	8.4	0.63	0.06	1.21
19	1	1	2	1	9	9.1	1.6	7.7	0.51	0.13	0.39
20	1	1	2	1	10	8.3	2.3	8.3	0.75	0.11	0.75
21	1	1	2	2	1	8.3	2.3	4.1	0.69	0.03	0.88
22	1	1	2	2	2	8.3	2.6	3.0	0.41	0.03	0.65
23	1	1	2	2	3	8.4	2.3	3.0	0.89	0.01	0.93
24	1	1	2	2	4	7.6	2.1	4.1	0.75	0.01	0.64
25	1	1	2	2	5	8.3	2.0	3.6	0.88	0.04	0.78
26	1	1	2	2	6	9.0	1.6	3.6	0.70	0.06	0.77
27	1	1	2	2	7	8.0	2.3	3.6	1.07	0.01	0.87
28	1	1	2	2	8	7.9	2.2	3.9	1.00	0.01	1.07
29	1	1	2	2	9	9.1	2.1	3.0	0.81	0.03	0.85
30	1	1	2	2	10	9.4	2.0	3.6	0.97	0.04	0.71
31	1	1	2	2	11	6.3	2.3	6.7	0.95	0.04	1.01
32	1	1	2	2	12	8.4	2.4	6.4	0.95	0.02	0.84
33	1	1	2	2	13	7.6	2.8	7.8	1.01	0.03	1.09
34	1	1	2	2	14	7.8	2.3	7.4	0.81	0.03	0.88
35	1	1	2	2	15	8.3	2.1	8.0	0.88	0.03	0.86
36	1	1	3	1	1	8.3	2.2	4.6	0.43	0.11	1.33
37	1	1	3	1	2	8.3	1.6	3.4	0.56	0.11	0.88
38	1	1	3	1	3	9.9	2.0	4.7	0.70	0.13	0.82
39	1	1	3	1	4	8.7	2.1	2.9	0.69	0.11	1.01
40	1	1	3	1	5	8.6	1.9	4.3	0.72	0.11	0.87
41	1	1	3	1	6	8.3	2.0	4.7	0.65	0.13	0.78
42	1	1	3	1	7	8.4	2.0	4.3	0.73	0.13	0.83
43	1	1	3	1	8	8.4	1.9	3.7	0.44	0.10	0.69
44	1	1	3	1	9	8.4	2.0	5.6	0.86	0.11	0.71
45	1	1	3	1	10	7.6	1.8	4.7	0.77	0.11	1.01
46	1	2	4	1	1	9.2	2.8	5.1	0.43	0.15	1.22
47	1	2	4	1	2	8.4	2.1	3.3	1.05	0.16	1.06
48	1	2	4	1	3	8.6	2.3	4.0	0.76	0.16	1.27
49	1	2	4	1	4	8.7	2.3	3.7	1.03	0.14	1.21
50	1	2	4	1	5	8.7	2.6	3.4	0.94	0.16	1.23
51	1	2	4	1	6	8.6	2.2	3.7	0.95	0.16	1.29
52	1	2	4	1	7	8.3	2.5	4.0	0.60	0.18	1.25
53	1	2	4	1	8	8.1	2.2	5.6	0.98	0.10	1.28
54	1	2	4	1	9	9.1	1.4	5.9	1.04	0.14	1.05
55	1	2	4	1	10	8.6	1.9	8.3	0.46	0.14	1.31
56	1	2	4	2	1	9.6	2.7	5.7	0.54	0.06	1.00
57	1	2	4	2	2	7.8	2.6	5.9	0.80	0.04	1.06
58	1	2	4	2	3	7.9	2.3	5.9	0.57	0.06	1.03
59	1	2	4	2	4	7.4	2.3	5.6	0.42	0.06	1.06
60	1	2	4	2	5	7.4	2.8	5.8	0.70	0.06	1.05

BLOOD DATA

OBS	SEX	RUG	DST	SPC	SPL	BS_CA	BS_MG	BS_P	BS_CU	BS_SE	BS_ZN
61	1	2	4	7	6	7.8	1.5	5.8	0.72	0.06	0.85
62	1	2	4	7	7	8.6	2.1	7.9	0.74	0.06	1.11
63	1	2	4	2	8	8.9	2.0	6.6	0.58	0.06	0.95
64	1	2	4	2	9	8.8	2.1	7.5	0.87	0.06	1.10
65	1	2	4	2	10	6.8	2.2	8.0	0.81	0.14	1.14
66	1	2	4	2	11	8.7	2.0	5.1	0.88	0.06	1.32
67	1	2	4	2	12	7.9	2.1	3.5	1.25	0.05	0.66
68	1	2	5	1	1	8.3	2.0	6.1	0.66	0.13	1.20
69	1	2	5	1	2	8.0	1.9	6.2	0.93	0.17	1.17
70	1	2	5	1	3	8.5	2.4	6.3	0.66	0.15	0.83
71	1	2	5	1	4	9.1	2.5	6.4	0.41	0.14	0.98
72	1	2	5	1	5	7.9	2.2	6.0	0.87	0.10	1.08
73	1	7	5	1	6	7.8	2.1	6.0	0.66	0.14	0.86
74	1	2	5	1	7	7.9	2.5	6.1	0.73	0.13	1.13
75	1	2	5	1	8	8.0	1.9	6.2	0.77	0.13	1.06
76	1	2	5	1	9	8.5	2.0	8.0	0.72	0.13	1.10
77	1	2	5	1	10	8.7	2.2	5.7	0.81	0.16	0.87
78	1	2	5	2	1	8.1	2.3	5.9	1.06	0.03	1.12
79	1	2	5	2	2	8.0	2.4	3.8	0.99	0.03	1.06
80	1	2	5	2	5	8.6	2.6	6.0	0.96	0.04	0.83
81	1	2	5	2	4	8.3	2.0	8.3	1.03	0.08	0.93
82	1	2	5	2	3	8.5	2.4	5.7	0.77	0.04	0.96
83	1	2	5	2	6	8.8	2.8	5.9	0.85	0.03	1.10
84	1	2	5	2	7	8.0	2.7	6.0	0.74	0.08	1.08
85	1	2	5	2	8	7.9	2.0	4.9	0.66	0.08	1.06
86	1	2	5	2	9	9.2	2.1	4.8	0.66	0.03	1.01
87	1	2	5	2	10	8.1	2.3	5.9	0.66	0.03	1.17
88	1	2	5	2	11	8.3	2.0	8.1	0.60	0.03	1.20
89	1	2	5	2	12	8.0	1.9	6.2	1.03	0.06	1.17
90	1	2	6	1	1	8.5	2.8	7.0	0.85	0.12	1.50
91	1	2	6	1	2	8.5	2.4	7.0	1.15	0.12	1.15
92	1	2	6	1	3	8.4	2.4	6.1	0.88	0.12	1.36
93	1	2	6	1	4	7.9	1.8	8.6	0.79	0.12	1.25
94	1	2	6	1	5	9.1	1.9	5.4	0.78	0.15	1.27
95	1	2	6	1	6	8.4	2.7	8.6	0.85	0.14	1.13
96	1	2	6	1	7	8.8	2.2	6.0	0.90	0.14	1.31
97	1	2	6	1	8	8.2	2.1	6.3	0.64	0.14	1.03
98	1	2	6	1	9	8.2	2.7	6.7	0.76	0.14	1.08
99	1	2	6	1	10	8.5	2.5	8.4	0.88	0.12	1.28
100	1	3	7	1	1	8.4	2.6	6.6	0.50	0.21	0.56
101	1	3	7	1	2	8.4	2.5	5.7	0.57	0.14	0.61
102	1	3	7	1	3	7.9	2.6	7.5	0.65	0.15	0.74
103	1	3	7	1	4	8.7	2.3	6.7	0.64	0.11	0.47
104	1	3	7	1	5	8.4	2.6	3.4	0.43	0.16	0.86
105	1	3	7	1	6	8.4	2.7	8.1	0.88	0.14	0.42
106	1	3	7	1	7	7.8	2.8	7.1	0.64	0.14	0.54
107	1	3	7	1	8	8.4	2.5	7.5	0.51	0.14	0.50
108	1	3	7	1	9	8.4	2.5	6.2	0.50	0.13	0.75
109	1	3	7	1	10	8.2	2.4	8.7	0.66	0.15	1.03
110	1	3	8	1	1	8.0	2.5	6.2	0.79	0.11	0.86
111	1	3	8	1	2	8.4	2.0	5.5	0.85	0.10	1.33
112	1	3	8	1	3	9.1	2.0	8.8	0.76	0.11	1.03
113	1	3	8	1	4	8.4	2.4	5.8	0.59	0.16	0.79
114	1	3	8	1	5	8.4	2.5	6.4	0.75	0.16	1.10
115	1	3	8	1	6	9.2	2.6	5.9	0.84	0.11	1.08
116	1	3	8	1	7	9.2	2.5	5.1	0.66	0.14	1.39
117	1	3	8	1	8	9.4	2.5	6.3	0.66	0.10	1.23
118	1	3	8	1	9	8.7	2.6	5.8	0.57	0.10	1.54
119	1	3	8	1	10	8.8	5.0	6.2	0.77	0.10	1.08
120	1	3	9	1	1	6.6	2.6	5.7	0.93	0.06	1.14

BLOOD DATA

OBS	SEX	AGE	SST	SPC	SPL	BP_CA	BS_MG	BP_P	BS_CU	BS_FE	BS_ZN
121	1	3	9	1	2	8.1	2.5	3.6	1.07	0.06	0.68
122	1	3	9	1	3	8.5	2.4	3.0	1.06	0.10	0.76
123	1	3	9	1	4	8.2	2.7	1.7	1.12	0.07	1.07
124	1	3	9	1	5	8.3	2.4	2.0	0.96	0.11	0.81
125	1	3	9	1	6	8.3	2.5	3.3	1.06	0.06	0.75
126	1	3	9	1	7	8.4	2.7	2.5	0.91	0.06	0.79
127	1	3	9	1	8	8.4	2.7	2.4	1.07	0.06	0.95
128	1	3	9	1	9	8.4	2.6	2.3	0.86	0.08	0.85
129	1	3	9	1	10	8.9	2.9	2.3	0.95	0.08	0.86
130	1	3	9	2	1	8.4	3.0	1.6	0.86	0.06	0.86
131	1	3	9	2	2	8.4	2.7	1.7	0.95	0.06	1.03
132	1	3	9	2	3	8.4	2.9	1.6	0.94	0.06	1.06
133	1	3	9	2	4	7.2	2.8	1.5	0.86	0.07	0.97
134	1	3	9	2	5	7.7	2.8	2.4	0.96	0.07	1.38
135	1	3	9	2	6	7.4	2.6	2.4	1.08	0.07	0.75
136	1	3	9	2	7	7.9	2.9	1.4	1.13	0.07	0.86
137	1	3	9	2	8	8.9	2.7	1.9	1.13	0.08	1.05
138	1	3	9	2	9	9.1	3.0	1.5	0.92	0.07	0.84
139	1	3	9	2	10	8.4	2.7	1.9	0.88	0.06	1.16
140	1	3	9	2	11	8.9	2.8	3.7	0.93	0.06	1.14
141	1	3	9	2	12	8.1	2.6	5.6	1.27	0.06	0.86
142	1	3	9	2	13	8.2	2.4	3.0	1.32	0.10	0.78
143	1	3	9	2	14	8.2	2.3	1.7	1.22	0.07	1.07
144	1	3	9	2	15	8.3	2.5	2.6	0.94	0.11	0.81
145	1	3	9	2	16	8.3	2.2	3.3	1.22	0.06	0.75
146	1	3	9	2	17	8.4	2.3	2.4	1.11	0.06	0.79
147	1	3	9	2	18	8.4	2.5	2.3	1.07	0.06	0.95
148	1	3	9	2	19	8.4	2.4	2.3	1.08	0.06	0.95
149	1	3	10	1	1	8.9	2.0	6.5	0.75	0.11	1.26
150	1	3	10	1	2	8.5	2.6	5.1	0.97	0.19	1.06
151	1	3	10	1	3	8.4	2.1	3.3	0.72	0.22	0.92
152	1	3	10	1	4	9.2	2.6	5.1	0.86	0.22	0.99
153	1	3	10	1	5	9.1	2.3	4.1	0.86	0.17	0.91
154	1	3	10	1	6	9.2	2.6	5.4	0.77	0.17	1.27
155	1	3	10	1	7	8.7	2.8	6.2	0.77	0.08	1.06
156	1	3	10	1	8	8.5	2.9	6.3	0.91	0.19	1.06
157	1	3	10	1	9	8.4	2.8	5.8	1.09	0.19	1.06
158	1	3	10	1	10	8.1	1.3	3.3	0.79	0.13	0.92
159	2	1	1	1	1	8.7	2.7	5.3	0.57	0.06	0.67
160	2	1	1	1	2	9.1	2.8	6.7	0.57	0.06	0.78
161	2	1	1	1	3	8.3	2.7	4.4	0.81	0.06	0.88
162	2	1	1	1	4	8.7	2.8	5.1	0.55	0.04	0.77
163	2	1	1	1	5	8.9	3.9	4.8	0.57	0.08	0.77
164	2	1	1	1	6	8.2	2.8	4.6	0.57	0.08	0.64
165	2	1	1	1	7	8.1	2.3	9.1	0.62	0.06	0.78
166	2	1	1	1	8	7.8	2.4	3.8	0.64	0.08	0.78
167	2	1	1	1	9	9.2	2.9	9.1	0.77	0.06	0.57
168	2	1	1	1	10	8.2	2.4	6.5	0.77	0.11	0.55
169	2	1	2	1	1	8.4	2.4	7.5	0.50	0.06	0.80
170	2	1	2	1	2	8.6	2.5	5.9	0.75	0.04	0.63
171	2	1	2	1	3	8.7	3.0	5.2	0.58	0.05	0.66
172	2	1	2	1	4	8.3	2.8	5.4	0.68	0.08	0.61
173	2	1	2	1	5	8.3	2.7	5.6	0.67	0.25	0.55
174	2	1	2	1	6	8.8	3.4	8.0	0.53	0.08	0.55
175	2	1	2	1	7	8.8	3.0	5.9	0.55	0.06	0.66
176	2	1	2	1	8	8.4	2.5	3.4	0.55	0.03	0.75
177	2	1	2	1	9	8.4	2.2	4.7	0.39	0.03	0.65
178	2	1	2	1	10	8.4	2.5	3.7	0.60	0.04	0.80
179	2	1	2	2	1	7.8	2.7	4.9	0.66	0.03	0.77
180	2	1	2	2	2	9.1	2.4	4.6	0.50	0.04	0.93

BLOOD DATA

OBS	SEA	ARN	GSI	SPC	SPL	BB_CA	BB_MG	BB_P	BB_CU	BB_CD	BB_ZN
181	2	1	2	2	3	9.2	2.8	3.2	0.55	0.02	0.95
182	2	1	2	2	4	8.4	2.9	4.6	0.67	0.02	0.81
183	2	1	2	2	5	8.3	2.5	3.3	0.66	0.02	0.69
184	2	1	2	2	6	8.6	2.5	3.3	0.55	0.02	0.78
185	2	1	2	2	7	8.4	2.8	4.5	0.68	0.01	0.67
186	2	1	2	2	8	8.4	2.8	5.1	0.81	0.03	0.49
187	2	1	2	2	9	8.2	2.0	4.5	0.87	0.03	0.64
188	2	1	2	2	10	8.2	2.3	3.7	0.73	0.08	0.80
189	2	1	2	2	11	8.4	2.4	7.5	0.60	0.01	0.63
190	2	1	2	2	12	8.6	2.5	5.8	0.88	0.01	0.49
191	2	1	2	2	13	8.7	3.0	5.2	0.68	0.05	0.61
192	2	1	2	2	14	8.3	2.8	5.4	0.76	0.03	0.52
193	2	1	2	2	15	8.3	2.7	5.6	0.77	0.01	0.55
194	2	1	2	2	18	9.8	3.4	8.0	0.63	0.02	0.46
195	2	1	2	2	17	8.6	3.8	5.9	0.62	0.03	0.75
196	2	1	2	2	18	8.4	2.5	3.4	0.63	0.02	0.60
197	2	1	2	2	19	8.4	2.2	4.7	0.49	0.01	0.80
198	2	1	3	1	1	8.5	2.6	8.2	0.52	0.06	0.51
199	2	1	3	1	2	8.4	2.4	8.2	0.52	0.06	0.88
200	2	1	3	1	3	9.2	2.0	8.1	0.55	0.03	0.32
201	2	1	3	1	4	8.4	2.8	8.3	0.58	0.03	0.45
202	2	1	3	1	5	7.8	2.4	8.1	0.70	0.04	0.77
203	2	1	3	1	6	7.8	2.7	8.0	0.50	0.03	0.65
204	2	1	3	1	7	8.1	2.6	8.0	0.58	0.04	0.74
205	2	1	3	1	8	8.4	2.4	7.8	0.58	0.04	0.77
206	2	1	3	1	9	8.4	2.8	8.2	0.85	0.02	0.72
207	2	1	3	1	10	8.8	3.0	8.0	0.76	0.05	0.73
208	2	2	4	1	1	10.2	2.3	3.8	0.66	0.13	0.36
209	2	2	4	1	2	9.8	2.5	4.2	0.68	0.13	0.67
210	2	2	4	1	3	9.3	2.7	4.7	0.68	0.13	0.70
211	2	2	4	1	4	8.9	2.4	5.3	0.84	0.11	0.71
212	2	2	4	1	5	8.4	2.7	3.8	0.95	0.11	0.79
213	2	2	4	1	6	9.2	2.0	3.6	0.90	0.13	0.69
214	2	2	4	1	7	8.9	2.7	4.1	0.87	0.10	0.86
215	2	2	4	1	8	9.0	2.6	3.6	0.69	0.17	0.79
216	2	2	4	1	9	8.3	2.2	4.1	0.72	0.12	0.60
217	2	2	4	1	10	9.1	2.2	3.3	0.90	0.12	0.60
218	2	2	4	2	1	8.9	2.5	3.9	0.86	0.13	0.54
219	2	2	4	2	2	9.2	2.8	4.2	0.88	0.13	0.39
220	2	2	4	2	3	9.3	2.9	4.8	0.92	0.09	0.52
221	2	2	4	2	4	9.3	3.0	5.1	0.86	0.08	0.34
222	2	2	4	2	5	9.0	2.6	2.9	0.61	0.03	0.81
223	2	2	4	2	6	8.9	2.8	3.2	0.50	0.03	0.60
224	2	2	4	2	7	8.2	2.2	4.7	0.90	0.04	0.57
225	2	2	4	2	8	9.0	2.8	4.2	0.70	0.04	0.65
226	2	2	4	2	9	9.2	2.8	3.7	0.81	0.04	0.55
227	2	2	4	2	10	8.2	2.3	3.3	0.73	0.03	0.51
228	2	2	4	2	11	10.0	2.3	3.6	0.86	0.03	0.56
229	2	2	4	2	12	9.6	2.5	4.2	0.84	0.03	0.87
230	2	2	4	2	13	9.1	2.7	4.7	0.69	0.03	0.90
231	2	2	4	2	14	8.7	2.6	5.3	0.94	0.05	0.91
232	2	2	4	2	15	8.2	2.7	3.0	0.99	0.05	0.86
233	2	2	4	2	18	8.8	2.0	3.8	0.98	0.06	0.86
234	2	2	4	2	17	8.7	2.7	4.1	0.87	0.17	0.80
235	2	2	5	1	1	8.5	2.3	4.7	0.71	0.11	0.87
236	2	2	5	1	2	8.3	2.6	5.8	0.72	0.10	0.87
237	2	2	5	1	3	8.4	2.1	5.3	0.63	0.11	1.03
238	2	2	5	1	4	8.6	2.7	6.1	0.64	0.10	0.90
239	2	2	5	1	5	8.7	2.6	6.8	0.65	0.10	0.87
240	2	2	5	1	6	8.8	2.3	5.1	0.69	0.09	0.78

BLOOD DATA

OBS	SEX	AGE	CIT	SPC	SPL	BS_CA	BS_MG	BS_P	BS_CU	BS_MN	BS_ZN
241	2	2	5	1	7	9.3	2.2	5.3	0.37	0.04	0.79
242	2	2	5	1	8	8.8	2.4	6.3	0.32	0.04	0.81
243	2	2	5	1	9	8.8	2.5	4.0	0.63	0.11	0.87
244	2	2	5	1	10	8.7	2.3	5.1	0.67	0.12	0.85
245	2	2	5	2	1	8.8	2.4	5.2	0.71	0.02	0.88
246	2	2	5	2	2	8.4	2.8	5.3	0.65	0.01	0.91
247	2	2	5	2	3	8.3	2.3	6.7	0.41	0.01	0.77
248	2	2	5	2	4	9.0	2.4	6.0	0.64	0.03	0.78
249	2	2	5	2	5	8.7	2.1	4.7	0.73	0.03	0.70
250	2	2	5	2	6	8.3	2.6	6.3	0.74	0.02	0.79
251	2	2	5	2	7	8.4	2.3	5.2	0.67	0.02	0.67
252	2	2	5	2	8	8.3	2.5	5.7	0.66	0.05	0.82
253	2	2	5	2	9	8.8	2.4	7.0	0.60	0.04	0.80
254	2	2	5	2	10	8.8	2.3	4.7	0.71	0.05	0.77
255	2	2	5	2	11	8.8	2.6	3.0	0.72	0.02	0.93
256	2	2	5	2	12	8.7	2.1	5.3	0.63	0.03	0.86
257	2	2	5	2	13	8.8	2.7	4.1	0.64	0.07	0.77
258	2	2	5	2	14	8.8	2.4	4.0	0.65	0.04	0.68
259	2	2	5	2	15	9.1	2.3	5.1	0.68	0.01	0.66
260	2	2	6	1	1	7.8	2.4	4.8	0.85	0.06	0.86
261	2	2	6	1	2	8.8	2.1	3.7	0.87	0.06	0.86
262	2	2	6	1	3	8.2	2.4	7.0	0.63	0.17	1.05
263	2	2	6	1	4	8.5	2.4	7.2	1.13	0.07	1.33
264	2	2	6	1	5	9.1	2.5	6.8	1.13	0.06	1.39
265	2	2	6	1	6	9.3	2.3	6.3	0.79	0.04	0.83
266	2	2	6	1	7	8.4	2.7	5.1	0.70	0.11	0.95
267	2	2	6	1	8	7.8	2.6	4.8	0.43	0.07	0.80
268	2	2	6	1	9	8.3	2.7	5.2	0.52	0.07	1.00
269	2	2	6	1	10	8.4	2.3	3.6	0.79	0.08	0.90
270	2	3	7	1	1	9.3	2.4	6.8	0.68	0.11	0.66
271	2	3	7	1	2	8.6	2.7	4.8	0.68	0.11	0.60
272	2	3	7	1	3	8.8	2.7	3.3	0.37	0.11	0.48
273	2	3	7	1	4	8.8	2.1	3.1	0.68	0.07	0.41
274	2	3	7	1	5	8.4	2.3	3.8	0.72	0.07	0.41
275	2	3	7	1	6	9.4	2.4	5.2	0.74	0.07	0.66
276	2	3	7	1	7	8.0	2.5	6.7	0.68	0.10	0.37
277	2	3	7	1	8	8.2	3.4	6.1	0.67	0.17	0.37
278	2	3	7	1	9	8.6	2.4	2.7	0.43	0.08	0.38
279	2	3	7	1	10	8.8	2.3	6.0	0.88	0.12	0.90
280	2	3	8	1	1	8.6	1.9	4.1	0.82	0.16	0.75
281	2	3	8	1	2	8.4	2.2	3.3	0.95	0.07	0.68
282	2	3	8	1	3	8.3	2.2	3.5	0.60	0.07	0.71
283	2	3	8	1	4	8.3	2.3	4.3	0.62	0.07	0.76
284	2	3	8	1	5	8.6	2.2	4.1	0.58	0.13	0.48
285	2	3	8	1	6	8.3	2.4	3.9	0.33	0.10	0.62
286	2	3	8	1	7	8.2	2.4	5.6	0.88	0.13	0.37
287	2	3	8	1	8	7.8	1.9	4.0	0.98	0.07	0.66
288	2	3	8	1	9	8.3	3.2	3.6	0.80	0.11	0.53
289	2	3	8	1	10	8.3	2.2	3.7	0.39	0.13	0.53
290	2	3	9	1	1	9.0	2.6	6.6	0.53	0.12	0.81
291	2	3	9	1	2	9.1	2.5	4.7	0.59	0.12	0.82
292	2	3	9	1	3	8.1	2.6	5.1	0.59	0.16	0.88
293	2	3	9	1	4	7.8	2.7	4.7	0.69	0.14	0.69
294	2	3	9	1	5	9.2	2.7	3.1	0.81	0.11	0.79
295	2	3	9	1	6	8.8	3.0	7.8	0.59	0.11	0.65
296	2	3	9	1	7	8.7	2.4	5.4	0.47	0.13	0.78
297	2	3	9	1	8	8.8	2.3	4.2	0.62	0.15	0.86
298	2	3	9	1	9	8.8	3.5	4.1	0.45	0.11	0.66
299	2	3	9	1	10	8.2	2.5	3.8	0.61	0.07	0.86
300	2	3	9	2	1	8.2	2.6	3.0	0.53	0.09	0.39

BLOOD DATA

OBS	SEA	ESA	DBT	SPC	SPL	SP_CA	SS_MG	SP_P	SS_CU	SS_SE	SA_ZN
301	2	3	9	2	2	8.7	2.3	3.6	0.67	0.21	0.21
302	2	3	9	2	3	8.8	2.4	6.6	0.58	0.18	0.46
303	2	3	8	2	4	7.8	2.7	3.6	0.62	0.18	0.27
304	2	3	8	2	5	9.4	2.7	4.0	0.50	0.08	0.30
305	2	3	8	2	6	8.6	2.2	8.8	0.29	0.12	0.79
306	2	3	8	2	7	8.5	2.1	5.3	0.68	0.11	0.82
307	2	3	8	2	8	8.2	2.8	4.6	0.30	0.12	0.69
308	2	3	8	2	9	8.5	2.5	5.3	0.97	0.13	0.84
309	2	3	8	2	10	8.6	2.7	5.4	0.58	0.12	0.70
310	2	3	8	2	11	9.1	2.7	6.6	0.63	0.12	0.81
311	2	3	8	2	12	9.2	2.8	4.7	0.89	0.12	0.72
312	2	3	9	2	13	8.2	2.7	5.1	0.87	0.12	0.78
313	2	3	9	2	14	8.8	2.7	4.7	0.78	0.26	0.58
314	2	3	8	2	15	8.3	2.5	5.1	0.97	0.14	0.69
315	2	3	8	2	16	9.1	3.0	7.8	0.89	0.11	0.55
316	2	3	9	2	17	8.8	2.4	5.6	0.57	0.15	0.68
317	2	3	9	2	18	8.6	2.3	4.2	0.72	0.31	0.75
318	2	3	9	2	19	8.6	2.3	4.1	0.55	0.15	0.89
319	2	3	9	2	20	8.3	2.5	3.9	0.71	0.07	0.78
320	2	3	9	2	21	8.2	2.3	4.3	0.90	0.08	0.64
321	2	3	9	2	22	8.3	2.3	4.3	0.82	0.14	0.77
322	2	3	9	2	23	8.7	2.3	8.8	0.86	0.09	0.78
323	2	3	10	1	1	8.8	2.7	7.9	0.39	0.13	0.68
324	2	3	10	1	2	8.1	2.9	5.7	0.84	0.09	0.83
325	2	3	10	1	3	7.8	2.7	4.8	0.76	0.17	0.86
326	2	3	10	1	4	8.0	2.7	3.8	0.73	0.09	0.63
327	2	3	10	1	5	9.3	2.8	5.7	0.74	0.18	0.83
328	2	3	10	1	6	7.8	3.1	4.2	0.68	0.16	0.89
329	2	3	10	1	7	8.1	3.3	8.8	0.87	0.11	1.06
330	2	3	10	1	8	7.9	2.6	4.8	0.72	0.18	0.94
331	2	3	10	1	9	8.3	2.5	4.2	0.62	0.17	0.62
332	2	3	10	1	10	8.3	2.7	3.9	0.55	0.10	0.87

BONE DATA CODES

OBS = Observation number (1-332).

SEA = Season:
1. Rainy.
2. Dry.

RGN = Region.
1. Western.
2. Central.
3. Eastern.

DST = District:
1. Jeneponto.
2. Gowa
3. Barru.
4. Polmas.
5. Enrekang.
6. Sidrap.
7. Wajo.
8. Soppeng.
9. Bone.
10. Bulukumba.

SPC = Animal species:
1. Cattle.
2. Buffalo.

SPL = Sample number (1-23).

BO_CA = Bone calcium, % dry, fat-free basis.
BO_MG = Bone magnesium, % dry, fat-free basis.
BO_P = Bone phosphorus, % dry, fat-free basis.
BO_ASH = Bone ash, % dry, fat-free basis.
BO_SG = Bone specific gravity, g/cm^3 fresh basis.

BONE DATA

OBS	SEA	RGN	DST	SPC	SPL	60_CA	60_MG	60_P	60_ASH	60_SD
1	1	1	1	1	1	21.9	0.41	10.1	59.8	1.87
2	1	1	1	1	2	21.6	0.37	9.3	61.8	1.79
3	1	1	1	1	3	23.3	0.42	10.6	64.8	1.81
4	1	1	1	1	4	22.9	0.47	9.3	63.1	1.70
5	1	1	1	1	5	22.0	0.39	10.7	64.2	1.68
6	1	1	1	1	6	22.0	0.37	9.8	64.2	1.64
7	1	1	1	1	7	23.1	0.46	10.2	64.8	1.93
8	1	1	1	1	8	23.2	0.44	10.4	63.2	1.79
9	1	1	1	1	9	22.8	0.51	10.2	62.2	1.83
10	1	1	1	1	10	22.4	0.49	10.1	60.1	1.56
11	1	1	2	1	1	22.4	0.49	10.7	62.0	1.81
12	1	1	2	1	2	23.4	0.48	10.4	60.3	1.60
13	1	1	2	1	3	22.4	0.52	10.1	62.1	1.81
14	1	1	2	1	4	22.4	0.51	10.4	63.4	1.63
15	1	1	2	1	5	22.4	0.49	10.4	62.1	1.71
16	1	1	2	1	6	23.7	0.53	10.6	63.3	1.68
17	1	1	2	1	7	22.3	0.53	10.5	60.8	1.77
18	1	1	2	1	8	23.7	0.41	10.7	60.7	1.59
19	1	1	2	1	9	18.8	0.49	8.4	59.3	1.51
20	1	1	2	1	10	22.0	0.49	9.7	58.6	1.45
21	1	1	2	2	1	27.0	0.51	12.1	63.4	1.71
22	1	1	2	2	2	25.0	0.54	10.0	60.8	1.91
23	1	1	2	2	3	25.5	0.53	9.8	62.4	1.60
24	1	1	2	2	4	22.4	0.46	8.8	60.7	1.57
25	1	1	2	2	5	22.5	0.52	9.9	62.3	1.73
26	1	1	2	2	6	22.8	0.54	10.8	62.6	1.69
27	1	1	2	2	7	20.6	0.48	9.3	64.5	1.67
28	1	1	2	2	8	22.3	0.52	10.2	63.1	1.66
29	1	1	2	2	9	22.0	0.46	9.7	59.6	1.65
30	1	1	2	2	10	18.8	0.42	8.4	59.3	1.31
31	1	1	2	2	11	23.7	0.49	10.7	60.7	1.59
32	1	1	2	2	12	23.3	0.41	10.5	63.6	1.77
33	1	1	2	2	13	23.7	0.35	10.8	63.3	1.68
34	1	1	2	2	14	23.4	0.46	10.4	62.1	1.71
35	1	1	2	2	15	22.4	0.31	10.4	63.4	1.63
36	1	1	3	1	1	22.5	0.42	10.2	63.1	1.68
37	1	1	3	1	2	20.8	0.46	9.3	62.8	1.67
38	1	1	3	1	3	22.8	0.52	10.0	62.3	1.68
39	1	1	3	1	4	22.5	0.48	9.8	60.7	1.73
40	1	1	3	1	5	22.4	0.54	9.8	62.4	1.57
41	1	1	3	1	6	23.8	0.52	9.8	60.8	1.60
42	1	1	3	1	7	23.8	0.48	10.0	60.4	1.91
43	1	1	3	1	8	27.0	0.55	12.1	61.1	1.71
44	1	1	3	1	9	21.8	0.54	9.7	62.8	1.60
45	1	1	3	1	10	23.3	0.61	10.0	62.5	1.60
46	1	2	4	1	1	22.9	0.51	10.2	62.2	2.00
47	1	2	4	1	2	23.4	0.49	10.1	60.1	1.76
48	1	2	4	1	3	23.4	0.48	10.7	62.0	2.01
49	1	2	4	1	4	23.4	0.48	10.4	63.5	1.89
50	1	2	4	1	5	22.4	0.52	10.1	62.1	1.81
51	1	2	4	1	6	22.4	0.51	10.4	63.4	1.63
52	1	2	4	1	7	22.4	0.48	10.4	62.1	1.91
53	1	2	4	1	8	23.7	0.53	10.8	63.4	1.68
54	1	2	4	1	9	23.3	0.41	10.3	62.1	1.97
55	1	2	4	1	10	23.7	0.49	10.7	63.5	1.79
56	1	2	4	2	1	23.7	0.53	10.8	63.5	1.60
57	1	2	4	2	2	22.4	0.49	10.6	62.1	1.71
58	1	2	4	2	3	22.4	0.31	10.1	63.4	1.63
59	1	2	4	2	4	22.4	0.52	10.4	62.1	1.61
60	1	2	4	2	5	23.4	0.48	10.7	60.3	1.60

BONE DATA

OBS	SEX	RGN	EST	DPC	SPL	BB_CA	BB_MG	BB_P	BB_ASH	BB_SG
61	1	2	4	2	6	20.4	0.49	10.1	62.0	1.81
62	1	2	4	2	7	22.4	0.48	10.2	60.1	1.56
63	1	2	4	2	8	22.0	0.51	10.6	62.2	1.83
64	1	2	4	2	9	23.2	0.44	11.2	63.2	1.79
65	1	2	4	2	10	23.1	0.46	9.8	64.8	1.93
66	1	2	4	2	11	22.0	0.37	10.7	64.2	1.69
67	1	2	4	2	12	20.0	0.39	10.4	64.0	1.68
68	1	2	3	1	1	18.8	0.42	8.4	60.6	1.65
69	1	2	3	1	2	22.0	0.46	8.7	60.7	1.68
70	1	2	5	1	3	22.5	0.52	10.2	58.3	1.87
71	1	2	5	1	4	20.0	0.46	8.5	39.6	1.89
72	1	2	5	1	5	22.8	0.54	9.8	63.1	1.93
73	1	2	5	1	6	22.5	0.58	10.0	62.6	1.77
74	1	2	5	1	7	22.4	0.46	9.8	62.3	1.68
75	1	2	5	1	8	23.3	0.55	9.8	60.7	2.09
76	1	2	5	1	9	23.8	0.54	9.8	62.4	1.81
77	1	2	3	1	10	27.0	0.61	10.0	58.8	1.89
78	1	2	3	2	1	22.5	0.51	10.2	62.2	1.83
79	1	2	3	2	2	22.4	0.49	10.1	60.1	1.56
80	1	2	5	2	3	23.4	0.49	10.7	62.0	1.81
81	1	2	5	2	4	22.4	0.48	10.6	63.3	1.89
82	1	2	5	2	5	22.4	0.52	10.1	62.1	1.61
83	1	2	5	2	6	22.4	0.31	10.4	63.4	1.63
84	1	2	5	2	7	22.4	0.40	10.8	62.1	1.71
85	1	2	5	2	8	23.7	0.53	10.4	63.3	1.60
86	1	2	3	2	9	22.8	0.41	10.5	60.8	1.77
87	1	2	3	2	10	23.7	0.49	10.7	60.7	1.59
88	1	2	3	2	11	19.8	0.42	8.8	58.3	1.51
89	1	2	3	2	12	22.0	0.46	9.7	59.6	1.43
90	1	2	8	1	1	21.8	0.43	12.1	63.4	2.00
91	1	2	8	1	2	22.3	0.47	9.7	61.1	1.87
92	1	2	8	1	3	21.9	0.43	10.0	62.8	2.03
93	1	2	8	1	4	22.1	0.40	10.0	62.3	1.58
94	1	2	8	1	5	24.1	0.50	9.8	64.8	2.01
95	1	2	8	1	6	23.3	0.39	11.2	67.0	1.94
96	1	2	8	1	7	22.0	0.44	11.0	61.8	1.92
97	1	2	8	1	8	21.3	0.50	10.8	58.0	1.94
98	1	2	8	1	9	22.0	0.41	9.3	63.8	1.56
99	1	2	8	1	10	23.4	0.38	10.4	67.6	2.23
100	1	3	7	1	1	22.5	0.41	10.5	60.8	1.77
101	1	3	7	1	2	23.7	0.49	10.7	60.7	1.56
102	1	3	7	1	3	18.8	0.42	8.6	56.5	1.31
103	1	3	7	1	4	22.0	0.46	9.7	59.6	1.43
104	1	3	7	1	5	22.5	0.52	10.2	65.1	1.60
105	1	3	7	1	6	20.0	0.48	9.8	63.8	1.87
106	1	3	7	1	7	22.8	0.54	10.0	62.8	1.60
107	1	3	7	1	8	22.3	0.52	9.8	62.3	1.73
108	1	3	7	1	9	22.4	0.46	9.8	60.7	1.37
109	1	3	7	1	10	23.8	0.55	9.8	62.4	1.68
110	1	3	8	1	1	23.8	0.34	10.0	60.9	1.61
111	1	3	8	1	2	27.0	0.41	12.1	63.4	1.71
112	1	3	8	1	3	21.5	0.46	9.7	61.1	1.60
113	1	3	8	1	4	22.3	0.47	10.0	52.0	1.60
114	1	3	8	1	5	23.0	0.43	10.0	62.3	1.63
115	1	3	8	1	6	22.1	0.40	9.8	62.6	1.56
116	1	3	8	1	7	24.1	0.60	10.2	64.0	2.01
117	1	3	8	1	8	23.3	0.39	11.0	67.0	1.94
118	1	3	8	1	9	22.0	0.44	9.3	61.8	1.60
119	1	3	8	1	10	21.3	0.38	10.4	58.0	1.60
120	1	3	8	1	1	22.6	0.41	9.8	63.8	1.68

BONE DATA

OBS	SEA	RGN	DST	SPC	SPL	AG_CA	AG_MG	AG_P	AG_ASH	AG_AB
121	1	3	9	1	2	29.4	0.38	9.9	67.4	1.36
122	1	3	9	1	3	21.4	0.45	9.3	60.5	1.93
123	1	3	9	1	4	22.2	0.47	8.4	61.5	1.69
124	1	3	9	1	5	22.4	0.32	9.4	64.9	1.85
125	1	3	9	1	6	23.5	0.68	9.5	65.2	2.31
126	1	3	9	1	7	25.1	0.40	10.9	68.4	2.16
127	1	3	9	1	8	24.8	0.39	11.1	66.3	1.64
128	1	3	9	1	9	21.3	0.36	11.1	56.0	1.75
129	1	3	9	1	10	24.0	0.34	9.9	65.1	1.64
130	1	3	9	2	1	23.2	0.44	10.4	63.2	1.78
131	1	3	9	2	2	23.1	0.68	10.2	64.5	1.93
132	1	3	9	2	3	22.0	0.37	8.6	56.9	1.69
133	1	3	9	2	4	22.0	0.39	10.7	56.9	1.86
134	1	3	9	2	5	22.9	0.47	9.3	63.1	1.78
135	1	3	9	2	6	23.3	0.62	10.6	66.8	1.81
136	1	3	9	2	7	21.6	0.97	8.5	61.6	1.75
137	1	3	9	2	8	21.9	0.41	10.1	59.8	1.87
138	1	3	9	2	9	25.4	0.33	8.4	67.4	1.97
139	1	3	9	2	10	25.4	0.36	8.3	97.8	1.92
140	1	3	9	2	11	23.0	0.44	11.4	65.0	1.81
141	1	3	9	2	12	22.1	0.49	10.0	68.2	1.85
142	1	3	9	2	13	21.3	0.38	8.3	86.7	1.36
143	1	3	9	2	14	26.5	0.38	10.3	69.5	2.36
144	1	3	9	2	15	23.7	0.35	10.4	65.5	1.60
145	1	3	9	2	16	22.5	0.33	10.3	64.3	1.73
146	1	3	9	2	17	26.5	0.39	12.9	72.8	1.91
147	1	3	9	2	18	25.3	0.59	12.9	56.2	1.64
148	1	3	9	2	19	24.0	0.34	8.4	65.1	1.75
149	1	3	10	1	1	25.3	0.59	9.4	56.2	1.81
150	1	3	10	1	2	26.5	0.59	12.9	72.8	1.75
151	1	3	10	1	3	22.3	0.33	12.9	56.3	1.68
152	1	3	10	1	4	23.7	0.35	10.3	65.5	2.06
153	1	3	10	1	5	24.3	0.36	10.4	65.5	1.38
154	1	3	10	1	6	21.3	0.36	10.3	58.7	1.85
155	1	3	10	1	7	22.1	0.40	9.3	62.2	1.71
156	1	3	10	1	8	23.0	0.44	10.0	63.0	1.92
157	1	3	10	1	9	29.4	0.36	11.4	97.9	1.97
158	1	3	10	1	10	23.4	0.33	9.4	67.4	1.87
159	2	1	1	1	1	21.8	0.45	9.7	61.1	1.64
160	2	1	1	1	2	22.3	0.47	10.0	52.8	1.75
161	2	1	1	1	3	21.9	0.43	10.0	68.3	1.72
162	2	1	1	1	4	22.1	0.40	9.8	62.6	1.78
163	2	1	1	1	5	24.1	0.38	10.2	56.8	1.94
164	2	1	1	1	6	23.3	0.39	11.0	97.9	1.96
165	2	1	1	1	7	22.8	0.44	10.8	61.0	1.79
166	2	1	1	1	8	21.3	0.38	8.3	58.8	1.85
167	2	1	1	1	9	22.6	0.41	10.4	86.6	1.77
168	2	1	1	1	10	25.4	0.34	9.9	67.4	1.87
169	2	1	2	1	1	21.4	0.45	9.3	86.3	1.78
170	2	1	2	1	2	22.2	0.47	9.4	91.9	1.88
171	2	1	2	1	3	22.4	0.32	9.5	64.9	1.64
172	2	1	2	1	4	23.5	0.68	10.9	65.2	1.78
173	2	1	2	1	5	26.1	0.40	11.1	68.4	2.26
174	2	1	2	1	6	24.8	0.39	11.1	68.3	2.11
175	2	1	2	1	7	21.3	0.36	8.6	68.0	1.79
176	2	1	2	1	8	24.0	0.34	8.4	65.1	1.68
177	2	1	2	1	9	35.3	0.59	12.8	56.2	1.59
178	2	1	2	1	10	26.3	0.39	10.3	72.8	1.60
179	2	1	2	2	1	65.4	0.36	8.4	67.4	1.97
180	2	1	2	2	2	25.4	0.44	8.3	67.9	1.92

BONE DATA

OBS	SEA	SIB	OST	SPC	SFL	BO_CA	BO_BD	BO_P	BO_ASH	BO_SG
181	2	1	2	2	3	25.0	0.40	11.4	63.0	1.91
182	2	1	2	2	4	22.1	0.64	10.0	62.2	1.85
183	2	1	2	2	5	24.5	0.80	9.3	30.7	1.91
184	2	1	2	2	6	25.7	0.35	10.5	65.5	1.89
185	2	1	2	2	7	22.5	0.33	10.4	65.5	1.56
186	2	1	2	2	8	28.3	0.34	10.5	44.3	2.08
187	2	1	2	2	9	25.3	0.59	12.9	72.8	1.89
188	2	1	2	2	10	26.0	0.34	12.9	44.2	1.73
189	2	1	2	2	11	21.5	0.38	9.4	65.1	1.91
190	2	1	2	2	12	24.9	0.38	8.6	60.0	1.64
191	2	1	2	2	13	25.1	0.40	11.3	60.3	1.73
192	2	1	2	2	14	23.5	0.38	11.1	66.4	1.86
193	2	1	2	2	15	22.4	0.32	10.6	60.2	2.18
194	2	1	2	2	16	22.2	0.47	9.5	64.9	2.31
195	2	1	2	2	17	21.4	0.45	6.4	81.5	1.83
196	2	1	2	2	18	23.4	0.80	9.3	66.3	1.80
197	2	1	2	2	19	22.8	0.41	9.6	27.4	1.93
198	2	1	3	1	1	22.5	0.33	10.5	64.3	1.64
199	2	1	3	1	2	23.7	0.35	9.3	65.5	1.34
200	2	1	3	1	3	24.5	0.38	10.0	65.3	2.11
201	2	1	3	1	4	21.5	0.64	11.4	58.7	1.31
202	2	1	3	1	5	22.1	0.40	9.3	63.2	1.80
203	2	1	3	1	6	[illegible]	0.64	9.6	63.0	1.80
204	2	1	3	1	7	25.4	0.36	10.1	67.9	1.92
205	2	1	3	1	8	25.4	0.33	9.5	67.4	1.82
206	2	1	3	1	9	21.9	0.41	10.4	39.8	1.70
207	2	1	3	1	10	21.6	0.17	9.5	61.9	1.76
208	2	2	4	1	1	22.8	0.41	10.4	65.6	1.82
209	2	2	4	1	2	25.6	0.38	9.6	67.4	1.92
210	2	2	4	1	3	21.4	0.45	9.3	60.3	1.84
211	2	2	4	1	4	22.2	0.47	9.4	61.3	1.93
212	2	2	4	1	5	22.6	0.32	8.5	64.9	1.89
213	2	2	4	1	6	23.3	0.38	10.8	69.2	1.83
214	2	2	4	1	7	25.1	0.40	11.5	60.4	2.31
215	2	2	4	1	8	24.9	0.39	11.1	66.3	2.16
216	2	2	4	1	9	21.5	0.36	8.8	64.0	1.84
217	2	2	4	1	10	24.0	0.34	9.4	65.1	1.73
218	2	2	4	2	1	24.9	0.38	11.1	64.3	2.16
219	2	2	4	2	2	25.1	0.40	11.1	80.4	2.31
220	2	2	4	2	3	23.5	0.64	10.8	80.2	1.83
221	2	2	4	2	4	22.4	0.32	9.5	60.9	1.89
222	2	2	4	2	5	21.4	0.62	9.4	81.5	1.93
223	2	2	4	2	6	25.4	0.65	9.3	80.5	1.86
224	2	2	4	2	7	20.8	0.38	9.8	87.4	1.80
225	2	2	4	2	8	21.3	0.41	10.4	65.6	1.82
226	2	2	4	2	9	22.0	0.38	9.3	38.9	1.38
227	2	2	4	2	10	25.3	0.44	10.8	61.0	1.84
228	2	2	4	2	11	24.1	0.38	11.0	67.9	2.01
229	2	2	4	2	12	20.1	0.80	10.2	64.8	1.80
230	2	2	4	2	13	21.9	0.48	9.9	32.6	1.83
231	2	2	4	2	14	22.3	0.43	10.0	62.3	1.77
232	2	2	4	2	15	21.8	0.45	10.0	62.0	1.80
233	2	2	4	2	16	22.0	0.41	9.7	61.1	1.69
234	2	2	4	2	17	25.0	0.56	12.1	65.4	1.71
235	2	2	3	1	1	25.3	0.39	12.9	64.2	1.64
236	2	2	3	1	2	24.3	0.39	12.9	72.8	1.91
237	2	2	3	1	3	22.5	0.33	10.3	64.3	1.75
238	2	2	3	1	4	23.2	0.33	10.6	65.3	1.80
239	2	2	3	1	5	26.3	0.38	10.3	65.3	2.06
240	2	2	3	1	6	21.5	0.64	9.3	80.7	1.80

BONE DATA

OBS	SEA	EGG	SRT	SPC	SPL	SO_CA	SO_MG	SO_P	SO_ASH	SO_SG
241	2	2	5	1	7	22.1	0.40	11.0	62.2	1.85
242	2	2	5	1	8	23.0	0.44	11.4	63.0	1.91
243	2	2	5	1	9	25.4	0.36	9.3	67.9	1.92
244	2	2	5	1	10	25.6	0.33	8.4	67.4	1.97
245	2	2	5	2	1	22.6	0.41	10.4	65.6	1.82
246	2	2	5	2	2	25.6	0.39	9.6	67.6	1.92
247	2	2	5	2	3	21.6	0.45	9.3	60.3	1.84
248	2	2	5	2	4	22.2	0.47	9.4	61.5	1.95
249	2	2	5	2	5	22.6	0.80	8.5	64.8	1.80
250	2	2	5	2	6	23.5	0.38	10.6	65.2	1.83
251	2	2	5	2	7	25.1	0.40	11.1	68.4	2.31
252	2	2	5	2	8	24.8	0.80	11.1	68.3	2.16
253	2	2	5	2	9	21.5	0.36	8.6	56.9	1.84
254	2	2	5	2	10	24.0	0.34	8.4	65.1	1.73
255	2	2	5	2	11	25.3	0.58	12.8	64.2	1.64
256	2	2	5	2	12	26.5	0.39	12.9	72.8	1.91
257	2	2	5	2	13	22.5	0.33	10.3	64.3	1.73
258	2	2	5	2	14	23.7	0.35	10.4	65.5	1.89
259	2	2	5	2	15	24.5	0.36	10.3	63.5	2.08
260	2	2	6	1	1	21.9	0.41	10.1	59.8	1.87
261	2	2	6	1	2	21.6	0.67	9.5	61.9	1.75
262	2	2	6	1	3	23.3	0.67	10.4	64.0	1.81
263	2	2	6	1	4	22.9	0.42	10.7	63.1	1.78
264	2	2	6	1	5	22.0	0.47	9.8	64.0	1.86
265	2	2	6	1	6	22.0	0.39	11.2	64.2	1.69
266	2	2	6	1	7	25.1	0.37	11.4	64.5	1.93
267	2	2	6	1	8	25.2	0.46	11.2	63.2	1.79
268	2	2	6	1	9	19.8	0.44	11.1	62.2	1.88
269	2	2	6	1	10	22.4	0.31	10.4	60.1	1.56
270	2	3	7	1	1	21.5	0.36	8.6	66.0	1.86
271	2	3	7	1	2	24.0	0.34	8.4	65.1	1.73
272	2	3	7	1	3	25.3	0.59	12.8	56.2	1.64
273	2	3	7	1	4	26.5	0.39	12.8	72.0	1.91
274	2	3	7	1	5	22.5	0.33	10.3	65.5	1.73
275	2	3	7	1	6	23.7	0.35	10.4	65.5	1.89
276	2	3	7	1	7	24.5	0.38	10.3	58.7	2.08
277	2	3	7	1	8	21.5	0.36	9.3	62.2	1.36
278	2	3	7	1	9	22.1	0.40	10.6	63.0	1.85
279	2	3	7	1	10	23.0	0.44	11.4	67.9	1.91
280	2	3	8	1	1	25.4	0.36	8.3	67.4	1.92
281	2	3	8	1	2	25.6	0.33	8.6	59.8	1.97
282	2	3	8	1	3	21.8	0.41	10.1	61.8	1.87
283	2	3	8	1	4	21.6	0.67	8.5	64.8	1.25
284	2	3	8	1	5	23.3	0.42	10.4	63.1	1.81
285	2	3	8	1	6	22.9	0.47	9.5	56.0	1.70
286	2	3	8	1	7	22.0	0.39	10.7	56.2	1.80
287	2	3	8	1	8	25.1	0.37	8.8	56.8	1.88
288	2	3	8	1	9	23.2	0.46	10.2	63.2	1.93
289	2	3	8	1	10	22.9	0.44	10.4	62.2	1.79
290	2	3	9	1	1	22.4	0.51	10.2	60.1	1.83
291	2	3	9	1	2	22.4	0.40	10.1	62.0	1.56
292	2	3	9	1	3	25.4	0.40	10.7	63.3	1.81
293	2	3	9	1	4	22.4	0.48	10.4	62.1	1.69
294	2	3	9	1	5	22.6	0.52	10.1	63.4	1.61
295	2	3	9	1	6	22.4	0.51	10.4	62.1	1.65
296	2	3	9	1	7	23.7	0.49	10.4	63.3	1.71
297	2	3	9	1	8	22.0	0.53	10.6	60.6	1.80
298	2	3	9	1	9	23.7	0.41	10.5	60.7	1.77
299	2	3	9	1	10	18.0	0.49	10.7	59.3	1.59
300	2	3	9	2	1	21.3	0.38	9.3	58.9	1.90

BONE DATA

OBS	SEA	RGN	DST	SPC	SPL	BO_CA	BO_MG	BO_P	BO_ASH	RT_SG
301	2	3	9	2	2	22.9	0.44	10.8	61.0	1.84
302	2	3	9	2	3	25.3	0.39	11.0	67.9	2.01
303	2	3	9	2	4	24.1	0.39	10.2	68.8	1.99
304	2	3	9	2	5	22.1	0.48	9.8	68.6	1.83
305	2	3	9	2	6	21.9	0.43	10.8	62.3	1.77
306	2	3	9	2	7	22.3	0.47	10.0	92.8	1.80
307	2	3	9	2	8	21.8	0.48	9.7	61.1	1.69
308	2	3	9	2	9	27.0	0.61	12.1	65.4	1.71
309	2	3	9	2	10	23.8	0.54	10.8	60.8	1.71
310	2	3	9	2	11	23.5	0.55	9.8	68.4	1.88
311	2	3	9	2	12	22.6	0.68	9.8	60.7	1.57
312	2	3	9	2	13	22.3	0.52	9.9	68.3	1.73
313	2	3	9	2	14	22.4	0.54	10.9	62.6	1.68
314	2	3	9	2	15	20.8	0.52	9.3	63.5	1.67
315	2	3	9	2	16	22.5	0.46	10.2	63.1	1.66
316	2	5	9	2	17	22.0	0.42	8.7	59.6	1.45
317	2	5	9	2	18	14.8	0.40	5.4	59.5	1.51
318	2	5	9	2	19	23.7	0.41	10.7	60.7	1.59
319	2	3	9	2	20	22.8	0.53	10.5	60.6	1.77
320	2	5	9	2	21	23.7	0.60	10.6	48.3	1.68
321	2	5	9	2	22	22.4	0.51	10.4	62.1	1.71
322	2	5	9	2	23	22.4	0.52	10.4	62.4	1.63
323	2	5	10	1	1	22.0	0.42	6.4	59.6	1.51
324	2	3	10	1	2	22.5	0.48	8.7	63.1	1.45
325	2	3	10	1	3	20.8	0.52	10.2	62.6	1.68
326	2	5	10	1	4	22.6	0.48	8.8	62.3	1.67
327	2	5	10	1	5	22.5	0.54	10.0	60.7	1.66
328	2	3	10	1	6	22.4	0.52	8.8	68.4	1.73
329	2	3	10	1	7	23.5	0.48	10.0	68.8	1.57
330	2	3	10	1	8	23.6	0.55	12.1	63.4	1.68
331	2	3	10	1	9	27.0	0.54	8.7	61.1	1.91
332	2	3	14	1	10	21.5	0.61	10.8	62.8	1.71

LIVER DATA CODES

OBS = Observation number (1-332).

SEA = Season: 1. Rainy.
2. Dry.

RGN = Region: 1. Western.
2. Central.
3. Eastern.

DST = District: 1. Jeneponto.
2. Gowa.
3. Barru.
4. Polmas.
5. Enrekang.
6. Sidrap.
7. Wajo.
8. Soppeng.
9. Bone.
10. Bulukumba.

SPC = Animal species: 1. Cattle.
2. Buffalo.

SPL = Sample number (1-23).

LI_CO = Liver cobalt, ppm dry basis.
LI_CU = Liver copper, ppm dry basis.
LI_FE = Liver iron, ppm dry basis.
LI_MN = Liver manganese, ppm dry basis.
LI_MO = Liver molybdenum, ppm dry basis.
LI_SE = Liver selenium, ppm dry basis.
LI_ZN = Liver zinc, ppm dry basis.

LIVER DATA

OBS	SEX	RGN	RAT	EPC	DPL	LI_CD	LI_CU	LI_FE	LI_MN	LI_MO	LI_SE	LI_ZN
1	1	1	1	1	1	0.40	46	253	7.6	2.61	0.40	91
2	1	1	1	1	2	0.63	72	391	11.7	2.07	0.28	100
3	1	1	1	1	3	0.42	66	356	13.2	3.32	0.37	118
4	1	1	1	1	4	0.79	42	336	11.5	4.00	0.39	105
5	1	1	1	1	5	0.67	68	452	12.2	4.09	0.43	155
6	1	1	1	1	6	0.41	79	467	5.7	5.74	0.41	153
7	1	1	1	1	7	0.44	47	274	8.1	5.60	0.37	128
8	1	1	1	1	8	0.97	68	326	5.8	1.15	0.58	154
9	1	1	1	1	9	0.27	71	205	8.6	2.20	0.68	66
10	1	1	1	1	10	0.22	68	399	6.5	1.60	0.91	133
11	1	1	2	1	1	0.43	69	252	8.8	4.78	0.12	99
12	1	1	2	1	2	0.49	85	421	12.3	2.08	0.22	68
13	1	1	2	1	3	0.31	76	223	12.1	3.00	0.14	114
14	1	1	2	1	4	0.61	99	405	15.5	4.11	0.27	108
15	1	1	2	1	5	0.42	78	364	10.0	2.31	0.23	101
16	1	1	2	1	6	0.31	91	331	9.8	2.73	0.20	110
17	1	1	2	1	7	0.43	79	279	5.3	4.68	0.29	146
18	1	1	2	1	8	0.31	72	327	8.0	2.47	0.21	95
19	1	1	2	1	9	1.10	66	439	4.2	2.18	1.51	158
20	1	1	2	1	10	0.78	71	464	8.8	5.17	0.60	107
21	1	1	2	2	1	0.35	147	274	8.4	3.77	0.29	93
22	1	1	2	2	2	1.12	156	601	8.8	3.17	0.21	121
23	1	1	2	2	3	0.78	141	666	10.1	5.22	0.29	160
24	1	1	2	2	4	1.10	156	439	4.2	2.10	0.20	138
25	1	1	2	2	5	0.31	92	327	8.0	2.47	0.23	95
26	1	1	2	2	6	0.43	66	279	3.3	4.40	0.27	146
27	1	1	2	2	7	0.51	141	281	8.6	2.73	0.16	110
28	1	1	2	2	8	0.42	168	364	10.0	2.31	0.22	101
29	1	1	2	2	9	0.41	109	405	13.3	4.11	0.12	108
30	1	1	2	2	10	0.31	98	223	12.1	3.00	0.28	114
31	1	1	2	2	11	0.49	185	421	12.5	2.68	0.33	88
32	1	1	2	2	12	0.45	135	252	9.8	4.78	0.44	89
33	1	1	2	2	13	0.36	168	483	15.5	3.55	0.30	142
34	1	1	2	2	14	0.42	88	257	8.2	4.83	1.48	154
35	1	1	2	2	15	0.80	108	451	11.6	2.56	1.58	132
36	1	1	3	1	1	0.41	66	338	8.8	2.73	0.41	93
37	1	1	3	1	2	0.62	75	471	4.2	2.92	0.49	124
38	1	1	3	1	3	0.27	72	358	6.0	3.53	0.58	118
39	1	1	3	1	4	0.54	71	514	9.1	3.78	0.48	128
40	1	1	3	1	5	0.62	88	259	5.5	3.62	0.39	123
41	1	1	3	1	6	0.37	88	727	12.3	2.27	0.33	102
42	1	1	3	1	7	0.64	52	501	15.2	3.83	0.28	160
43	1	1	3	1	8	0.35	48	287	10.2	2.31	0.12	154
44	1	1	3	1	9	0.42	53	451	11.4	2.24	0.22	114
45	1	1	3	1	10	0.60	78	257	11.6	2.56	0.14	132
46	1	2	4	1	1	0.42	159	295	4.3	3.11	0.71	128
47	1	2	4	1	2	0.63	159	210	8.2	2.44	0.72	102
48	1	2	4	1	3	0.49	88	227	11.3	2.40	0.81	143
49	1	2	4	1	4	0.33	156	260	5.6	1.60	0.70	110
50	1	2	4	1	5	0.38	155	251	5.6	2.40	0.61	146
51	1	2	4	1	6	0.54	159	263	6.1	3.05	0.56	97
52	1	2	4	1	7	0.61	155	169	4.6	5.08	0.39	68
53	1	2	4	1	8	0.57	152	160	4.4	2.45	0.09	117
54	1	2	4	1	9	0.58	153	258	6.5	2.41	0.81	81
55	1	2	4	1	10	0.48	181	282	5.6	2.60	0.60	73
56	1	2	4	2	1	0.43	168	298	7.8	2.81	0.45	68
57	1	2	4	2	2	0.69	107	286	7.1	2.80	1.39	79
58	1	2	4	2	3	0.43	161	282	5.8	2.61	0.88	73
59	1	2	4	2	4	0.58	175	258	8.5	2.43	0.41	81
60	1	2	4	2	5	0.57	172	186	4.4	3.08	0.50	117

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                                  LIVER DATA

OBS   MEA   RAN   RST   SPC   RPL   LI_CD  LI_CU  LI_FE  LI_MN  LI_MO  LI_SE  LI_ZN

 61    1     2     4     2     6    0.61    175    189    4.6   3.03   0.61    88
 62    1     2     4     2     7    0.64    179    263    6.1   2.40   0.52    97
 63    1     2     4     2     8    0.38    165    231    5.6   1.89   0.31   146
 64    1     2     4     2     9    0.39    158    269    5.6   2.40   0.29   117
 65    1     2     4     2    10    0.40    200    227   11.3   2.31   0.48   143
 66    1     2     4     2    11    0.43    175    210    8.2   2.69   0.36   108
 67    1     2     4     2    12    0.48    175    293    4.3   3.10   0.37   189
 68    1     2     5     1     1    0.30    169    266    4.7   3.12   0.47   101
 69    1     2     5     1     2    0.38    188    253    6.5   3.24   0.44   117
 70    1     2     5     1     3    0.43     89    264    7.6   3.20   0.51   115
 71    1     2     5     1     4    0.80    175    270    4.0   2.60   0.08   137
 72    1     2     5     1     5    0.49    109    303    9.0   3.10   0.47   108
 73    1     2     5     1     6    0.53    172    295    7.0   3.28   0.41    97
 74    1     2     5     1     7    0.48     94    289    7.0   2.50   0.51    94
 75    1     2     5     1     8    0.31    158    257    9.3   3.18   0.52    94
 76    1     2     5     1     9    0.31    109    214    9.0   3.10   0.44   107
 77    1     2     5     1    10    0.38    155    214    9.9   2.80   0.57   125
 78    1     2     5     2     1    0.55    183    341    5.3   2.97   0.32   197
 79    1     2     5     2     2    0.54    193    320    6.3   2.91   0.31   125
 80    1     2     5     2     3    0.55    173    214    9.9   3.17   0.21    94
 81    1     2     5     2     4    0.46    189    214    9.0   2.80   0.27    91
 82    1     2     5     2     5    0.89    176    257    9.3   3.11   0.69    94
 83    1     2     5     2     6    0.58    214    289    7.8   2.50   0.51    97
 84    1     2     5     2     7    0.41    192    295    7.0   3.29   0.26   109
 85    1     2     5     2     8    0.57    229    303    9.0   3.10   0.27   137
 86    1     2     5     2     9    0.68    195    271    6.0   2.90   0.23   115
 87    1     2     5     2    10    0.51    209    264    7.6   3.20   0.42   115
 88    1     2     5     2    11    0.44    188    253    6.5   3.24   0.31   117
 89    1     2     5     2    12    0.58    189    266    4.7   3.12   0.26   101
 90    1     2     6     1     1    0.37    108    270    4.0   1.60   0.45    76
 91    1     2     6     1     2    0.43    148    205    8.4   3.47   0.48   191
 92    1     2     6     1     3    0.40    116    559    1.7   4.58   0.81    95
 93    1     2     6     1     4    0.37    185    284    2.9   2.09   0.51    80
 94    1     2     6     1     5    0.37    189    333    4.7   3.24   0.46   139
 95    1     2     6     1     6    0.39    164    258    9.4   3.28   0.51   116
 96    1     2     6     1     7    0.39    118    347    4.5   2.57   0.62   126
 97    1     2     6     1     8    0.31    104    366    2.0   3.09   0.43   116
 98    1     2     6     1     9    0.49    109    273    4.8   2.96   0.47   123
 99    1     2     6     1    10    0.58    110    279    0.8   3.30   0.44    86
100    1     3     7     1     1    0.50     73    270    2.3   1.40   1.27    66
101    1     3     7     1     2    0.58     88    325   10.6   3.10   0.58   119
102    1     3     7     1     3    0.41    108    337    2.6   3.77   1.17   145
103    1     3     7     1     4    0.34     88    324    8.3   3.48   1.48   111
104    1     3     7     1     5    0.55    109    360   10.1   3.32   1.01   135
105    1     3     7     1     6    0.67    119    250    7.6   3.89   1.19   121
106    1     3     7     1     7    0.43     63    403    8.8   3.73   1.63   141
107    1     3     7     1     8    0.40     52    376   11.3   3.18   1.48   104
108    1     3     7     1     9    0.88     89    587    9.3   2.87   0.89   116
109    1     3     7     1    10    0.61     58    412    8.2   4.22   0.26   106
110    1     3     8     1     1    0.48     89    360    8.3   4.49   0.96   101
111    1     3     8     1     2    0.48     78    329    5.4   4.61   1.44   131
112    1     3     8     1     3    0.53     80    336    8.3   4.31   0.88   100
113    1     3     8     1     4    0.63     75    241   10.4   4.40   1.06    91
114    1     3     8     1     5    0.57     52    218    8.3   4.61   0.75   109
115    1     3     8     1     6    0.58     55    406   11.4   4.73   0.80    92
116    1     3     8     1     7    0.80     70    264    8.1   4.21   1.83    94
117    1     3     8     1     8    0.47     70    258    7.3   4.25   0.92    66
118    1     3     8     1     9    0.49     78    178    6.4   4.31   1.48    91
119    1     3     8     1    10    0.33     76    243    7.3   4.33   1.50    88
120    1     3     8     1     1    0.51    169    274   13.7   2.87   1.30   119
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LIVER DATA

OBS	SEA	RGN	OST	O/C	SPL	LI_CD	LI_CU	LI_FE	LI_MN	LI_MO	LI_SE	LI_ZN
121	1	3	0	1	2	0.60	151	297	14.8	2.35	0.92	112
122	1	5	0	1	3	0.46	209	218	17.2	2.80	1.64	110
123	1	5	0	1	4	0.47	109	364	15.6	1.07	1.80	143
124	1	3	0	1	5	0.35	122	283	8.5	5.41	0.96	129
125	1	3	0	1	6	0.50	218	131	13.0	5.08	1.32	153
126	1	3	0	1	7	0.36	174	332	14.4	3.60	1.40	143
127	1	3	0	1	8	0.32	128	209	8.0	1.15	0.60	109
128	1	3	0	1	9	0.27	160	197	11.3	3.17	0.96	130
129	1	5	0	1	10	0.47	193	505	13.9	3.47	1.24	124
130	1	3	0	2	1	0.54	237	213	14.3	1.96	0.36	129
131	1	3	0	2	2	0.35	150	213	8.8	3.78	0.50	112
132	1	3	0	2	3	0.37	243	305	14.8	3.47	0.32	124
133	1	3	0	2	4	0.37	150	197	12.3	3.17	0.60	150
134	1	3	0	2	5	0.45	176	289	10.0	1.15	1.10	108
135	1	3	0	2	6	0.46	224	332	15.4	3.88	0.64	145
136	1	3	0	2	7	0.60	368	551	14.9	5.28	0.62	133
137	1	3	0	2	8	0.45	172	483	8.3	3.41	0.20	129
138	1	3	0	2	9	0.37	340	384	14.6	1.47	2.30	143
139	1	3	0	2	10	0.56	369	418	18.2	2.88	0.60	118
140	1	3	0	2	11	0.60	221	497	15.0	2.35	1.09	112
141	1	3	0	2	12	0.81	213	474	4.7	2.87	0.73	116
142	1	3	0	2	13	0.78	179	230	6.0	3.91	2.32	123
143	1	3	0	2	14	0.63	147	345	8.3	3.63	1.07	94
144	1	3	0	2	15	0.71	85	912	8.2	4.22	0.89	108
145	1	3	0	2	16	0.70	130	487	10.5	2.07	1.17	116
146	1	3	0	2	17	0.52	88	576	12.5	3.10	2.19	104
147	1	3	0	2	18	0.55	73	703	8.8	3.73	1.23	161
148	1	3	0	2	19	0.77	110	250	6.6	5.82	1.31	121
149	1	3	10	1	1	0.78	88	321	6.3	3.16	1.35	112
150	1	3	10	1	2	0.40	74	356	4.7	4.87	1.88	141
151	1	3	10	1	3	0.51	74	376	8.7	6.09	1.46	85
152	1	3	10	1	4	0.45	83	336	8.4	5.07	1.20	89
153	1	3	10	1	5	0.40	75	468	6.5	4.24	1.10	103
154	1	3	10	1	6	0.82	82	515	12.0	2.56	1.51	95
155	1	5	10	1	7	0.43	83	481	6.0	3.13	1.23	95
156	1	3	10	1	8	0.36	72	368	7.0	4.39	1.29	96
157	1	3	10	1	9	0.44	77	575	7.0	4.41	1.27	96
158	1	3	10	1	10	0.60	91	351	7.3	3.60	1.29	103
159	2	1	1	1	1	0.60	88	338	10.0	3.42	0.42	105
160	2	1	1	1	2	0.83	53	276	7.8	5.28	0.58	174
161	2	1	1	1	3	0.57	89	472	7.8	3.40	0.34	137
162	2	1	1	1	4	0.44	88	363	10.8	4.31	0.88	88
163	2	1	1	1	5	0.52	57	385	11.4	2.30	0.29	151
164	2	1	1	1	6	0.73	36	453	8.8	3.60	0.45	101
165	2	1	1	1	7	0.80	72	349	14.4	2.64	0.57	100
166	2	1	1	1	8	0.50	40	260	14.8	2.73	0.35	160
167	2	1	1	1	9	0.37	50	517	10.6	3.23	1.40	120
168	2	1	1	1	10	0.54	37	408	11.3	2.88	1.29	97
169	2	1	2	1	1	0.09	33	380	13.0	2.09	0.07	95
170	2	1	2	1	2	0.31	24	277	10.8	2.63	0.15	109
171	2	1	2	1	3	0.70	33	584	10.3	3.14	0.88	66
172	2	1	2	1	4	0.41	13	291	12.7	2.36	0.13	101
173	2	1	2	1	5	0.45	40	399	15.8	5.59	0.12	123
174	2	1	2	1	6	0.47	41	336	17.1	2.84	0.14	77
175	2	1	2	1	7	0.31	44	487	14.0	3.69	0.21	113
176	2	1	2	1	8	0.46	28	370	14.0	3.11	0.31	95
177	2	1	2	1	9	0.61	32	399	11.5	2.96	0.32	81
178	2	1	2	1	10	0.32	56	343	12.6	3.55	0.37	115
179	2	1	2	2	1	0.60	220	755	16.0	2.73	0.17	132
180	2	1	2	2	2	0.90	58	336	10.2	3.72	0.11	151

LIVER DATA

OBS	SEX	EGA	AGT	NPC	SPL	LI_CD	LI_CU	LI_FE	LI_MN	LI_MO	LI_SE	LI_ZN
181	2	1	2	2	3	0.66	43	605	15.6	5.53	0.14	115
182	2	1	2	2	4	0.42	42	345	12.5	2.96	0.12	91
183	2	1	2	2	5	0.56	78	544	18.0	3.11	0.13	85
184	2	1	2	2	6	0.41	166	570	18.8	5.05	0.06	103
185	2	1	2	2	7	0.77	31	487	17.1	2.84	0.15	77
186	2	1	2	2	8	0.95	100	330	15.9	5.39	0.07	123
187	2	1	2	2	9	0.51	95	399	12.7	2.56	0.15	171
188	2	1	2	2	10	0.46	103	291	16.3	5.14	0.18	86
189	2	1	2	2	11	0.41	94	596	16.8	2.83	0.17	106
190	2	1	2	2	12	0.57	83	277	13.0	2.49	0.11	95
191	2	1	2	2	13	0.67	137	280	17.1	2.30	0.12	101
192	2	1	2	2	14	0.86	205	456	12.6	4.26	0.24	127
193	2	1	2	2	15	0.46	127	407	17.2	2.86	0.12	86
194	2	1	2	2	16	0.86	75	512	13.3	1.15	0.21	119
195	2	1	2	2	17	0.63	339	425	19.8	3.87	0.45	113
196	2	1	2	2	18	0.86	212	394	11.6	3.31	0.39	186
197	2	1	2	2	19	0.58	382	401	13.9	3.02	0.21	126
198	2	1	3	1	1	0.48	53	452	13.2	2.77	0.32	106
199	2	1	3	1	2	0.55	45	250	15.2	1.96	0.44	110
200	2	1	3	1	3	0.59	57	811	10.8	3.00	0.39	149
201	2	1	3	1	4	0.52	27	755	15.0	3.71	0.31	158
202	2	1	3	1	5	0.49	52	411	13.4	3.02	0.37	126
203	2	1	3	1	6	0.86	42	396	19.8	3.30	0.39	128
204	2	1	3	1	7	0.53	59	425	10.8	3.87	0.41	103
205	2	1	3	1	8	0.48	86	353	12.3	1.15	0.35	119
206	2	1	3	1	9	0.49	27	512	18.2	2.96	0.31	96
207	2	1	3	1	10	0.80	85	607	11.8	4.26	0.39	127
208	2	2	4	1	1	0.49	122	186	5.4	5.38	0.51	92
209	2	2	4	1	2	0.38	183	320	5.7	3.66	0.87	131
210	2	2	4	1	3	0.45	151	228	10.8	2.88	0.48	66
211	2	2	4	1	4	0.41	121	233	9.2	3.57	0.59	39
212	2	2	4	1	5	0.53	130	352	8.2	5.86	0.81	117
213	2	2	4	1	6	0.49	131	586	11.0	3.11	0.71	86
214	2	2	4	1	7	0.47	121	252	8.8	2.51	0.86	113
215	2	2	4	1	8	0.58	128	226	7.7	2.44	1.15	86
216	2	2	4	1	8	0.33	129	305	7.0	2.86	0.71	77
217	2	2	4	1	10	0.39	130	271	8.5	5.01	0.65	102
218	2	2	4	2	1	0.44	150	327	8.8	2.23	0.56	101
219	2	2	4	2	2	0.43	166	271	10.5	2.49	0.59	107
220	2	2	4	2	3	0.39	96	305	10.5	5.01	0.41	108
221	2	2	4	2	4	0.33	129	309	8.8	2.48	0.51	77
222	2	2	4	2	5	0.86	128	226	8.7	2.44	0.29	89
223	2	2	4	2	6	0.47	151	252	8.8	2.31	0.38	113
224	2	2	4	2	7	0.49	121	586	12.0	3.11	0.37	39
225	2	2	4	2	8	0.55	120	552	8.2	3.48	0.21	117
226	2	2	4	2	9	0.41	161	233	10.2	3.57	0.79	39
227	2	2	4	2	10	0.45	151	228	11.0	3.96	0.71	66
228	2	2	4	2	11	0.86	265	320	8.7	5.86	0.29	151
229	2	2	4	2	12	0.49	112	156	8.4	5.38	0.81	92
230	2	2	4	2	13	0.57	71	164	5.9	2.86	0.10	45
231	2	2	4	2	14	0.53	175	321	8.8	2.29	0.86	115
232	2	2	4	2	15	0.62	224	425	9.4	2.87	0.43	151
233	2	2	4	2	16	0.63	239	486	3.7	2.34	0.21	123
234	2	2	4	2	17	0.49	240	425	8.3	5.72	0.33	106
235	2	2	5	1	1	0.44	88	255	6.3	2.71	0.50	80
236	2	2	5	1	2	0.53	110	280	9.0	3.40	0.62	107
237	2	2	5	1	3	0.86	91	242	6.5	3.53	0.55	84
238	2	2	5	1	4	0.86	118	316	8.0	3.40	0.55	92
239	2	2	5	1	5	0.39	117	388	9.8	3.39	0.49	105
240	2	2	5	1	6	0.48	119	244	6.2	3.43	0.47	110

LIVER DATA

OBS	SOA	RSB	DOT	WPC	TPL	LI_CD	LI_CU	LI_FE	LI_MN	LI_MO	LI_SE	LI_ZN
241	2	2	5	1	2	0.54	95	205	8.8	5.01	0.63	104
242	2	2	5	1	3	0.40	131	216	8.7	2.97	0.31	114
243	2	2	5	1	6	0.47	94	186	8.8	5.51	0.73	119
244	2	2	5	1	10	0.43	114	216	10.1	5.33	0.84	87
245	2	2	5	2	1	0.41	172	228	8.1	5.81	0.41	121
246	2	2	5	2	2	0.43	158	221	8.0	5.37	0.55	86
247	2	2	3	2	3	0.40	144	216	10.6	5.33	0.37	87
248	2	2	3	2	4	0.42	124	184	8.6	5.31	0.64	119
249	2	2	3	2	5	0.84	191	214	13.5	2.97	0.45	104
250	2	2	3	2	6	0.84	125	298	10.8	5.01	0.52	104
251	2	2	3	2	7	0.84	146	244	6.0	5.45	0.40	110
252	2	2	5	2	8	0.84	142	388	11.8	5.39	0.33	106
253	2	2	5	2	9	0.84	184	316	8.8	5.40	0.28	93
254	2	2	5	2	10	0.50	131	242	7.5	5.53	0.38	94
255	2	2	5	2	11	0.53	150	260	6.8	5.40	0.18	112
256	2	2	5	2	12	0.49	132	258	2.1	2.21	0.42	90
257	2	2	5	2	15	0.84	149	466	4.5	3.95	0.15	115
258	2	2	5	2	14	0.81	146	466	2.2	3.29	0.53	107
259	2	2	5	2	13	0.61	122	498	6.4	3.36	0.12	164
260	2	2	6	1	1	0.49	198	441	2.4	2.67	0.22	97
261	2	2	8	1	2	0.58	114	474	2.6	3.51	0.63	157
262	2	2	8	1	3	0.53	98	297	8.9	3.44	0.23	121
263	2	2	8	1	4	0.55	198	384	5.3	3.42	0.52	147
264	2	2	6	1	5	0.53	98	576	0.7	5.38	0.29	85
265	2	2	6	1	6	0.81	122	468	8.2	3.31	0.84	104
266	2	2	6	1	7	0.56	101	468	8.8	2.97	0.86	104
267	2	2	8	1	8	0.34	99	391	9.7	2.74	0.43	155
268	2	2	6	1	9	0.53	115	495	3.8	5.28	0.50	115
269	2	2	8	1	10	0.61	90	468	8.6	5.36	0.62	164
270	2	3	7	1	1	0.53	86	205	13.8	5.11	0.98	85
271	2	3	7	1	2	0.58	90	236	14.0	5.47	0.36	105
272	2	5	7	1	3	0.58	72	382	10.1	4.22	1.10	90
273	2	5	7	1	4	0.60	117	227	10.1	5.17	1.61	108
274	2	5	7	1	5	0.90	78	263	10.0	2.51	0.98	106
275	2	3	7	1	6	0.95	175	250	10.9	4.63	1.24	98
276	2	5	7	1	7	0.83	97	311	15.5	4.40	0.91	86
277	2	3	7	1	8	0.71	75	241	17.2	5.77	1.42	83
278	2	3	7	1	9	0.77	90	344	14.8	5.67	0.72	93
279	2	3	7	1	10	0.48	119	362	12.6	4.53	1.15	82
280	2	3	8	1	1	0.57	98	251	10.1	4.61	1.34	110
281	2	5	8	1	2	0.53	105	195	9.0	4.60	1.44	98
282	2	5	8	1	3	0.49	133	143	12.4	4.43	0.78	121
283	2	5	8	1	4	0.48	98	511	11.3	4.18	0.84	117
284	2	5	8	1	5	0.81	98	218	10.4	4.90	1.30	104
285	2	5	8	1	6	0.71	97	491	10.6	5.81	0.81	90
286	2	3	8	1	7	0.42	98	310	9.9	8.01	0.86	94
287	2	5	8	1	8	0.65	112	283	10.4	5.40	0.98	113
288	2	3	8	1	9	0.84	76	198	11.2	5.18	1.22	92
289	2	3	8	1	10	0.43	59	362	9.9	4.90	1.02	98
290	2	3	9	1	1	0.50	93	446	11.3	4.18	1.08	121
291	2	3	9	1	2	0.53	72	314	14.2	2.98	0.63	153
292	2	5	9	1	3	0.84	199	541	12.1	2.81	0.98	104
293	2	5	9	1	4	0.84	98	186	14.7	4.31	0.98	95
294	2	5	9	1	5	0.52	132	598	11.8	3.55	0.71	121
295	2	5	9	1	6	0.52	85	481	13.1	4.37	1.33	117
296	2	5	9	1	7	0.47	197	298	12.8	4.98	1.69	104
297	2	5	9	1	8	0.53	184	143	8.5	4.78	1.54	101
298	2	5	9	1	9	0.43	105	277	11.7	5.06	1.66	125
299	2	5	9	1	10	0.46	97	215	8.8	2.34	0.78	106
300	2	5	9	2	1	0.63	75	468	15.7	5.69	1.49	90

LIVER DATA

OBS	SEA	BSR	BS1	RPC	SPL	LI_CD	LI_CU	LI_FE	LI_MG	LI_MN	LI_SE	LI_ZN
301	2	3	9	2	2	0.86	77	263	11.4	4.35	1.71	94
302	2	3	9	2	3	0.63	80	478	11.3	2.34	1.53	105
303	2	3	9	2	4	0.73	83	413	13.1	3.08	1.51	109
304	2	3	9	2	5	0.67	87	477	14.9	4.78	1.43	101
305	2	3	9	2	6	0.72	93	343	15.1	4.80	1.48	106
306	2	3	9	2	7	0.77	73	494	13.8	4.37	1.13	117
307	2	3	9	2	8	0.80	100	951	19.7	3.53	1.50	121
308	2	3	9	2	9	0.88	80	789	14.1	4.31	0.32	93
309	2	3	9	2	10	0.73	88	388	18.2	2.81	0.33	108
310	2	3	9	2	11	0.70	67	541	18.8	2.92	0.51	133
311	2	3	9	2	12	0.53	75	314	8.6	4.18	0.32	121
312	2	3	9	2	13	0.41	129	568	7.9	4.43	0.31	121
313	2	3	9	2	14	0.35	121	324	7.9	5.11	0.33	71
314	2	3	9	2	15	0.63	218	292	6.5	2.86	0.31	108
315	2	3	9	2	16	0.37	231	314	5.8	4.69	0.86	108
316	2	3	9	2	17	0.52	97	279	7.1	4.63	0.58	89
317	2	3	9	2	18	0.88	138	589	10.4	3.75	0.57	91
318	2	3	9	2	19	0.87	178	546	14.4	3.11	0.51	76
319	2	3	9	2	20	0.88	203	468	14.8	3.88	0.53	121
320	2	3	9	2	21	0.47	111	218	19.9	4.09	0.59	146
321	2	3	9	2	22	0.50	82	262	14.3	7.70	0.57	106
322	2	3	9	2	23	0.58	280	186	9.9	2.80	0.38	93
323	2	3	10	1	1	0.33	86	314	11.1	2.57	0.66	108
324	2	3	10	1	2	0.48	84	336	15.3	2.63	1.22	109
325	2	3	10	1	3	0.57	88	305	12.3	3.45	1.17	95
326	2	3	10	1	4	0.71	97	186	13.9	4.19	0.71	86
327	2	3	10	1	5	0.67	79	578	11.3	3.41	0.86	136
328	2	3	10	1	6	0.86	86	795	12.3	4.86	0.86	110
329	2	3	10	1	7	0.86	86	348	13.0	8.80	1.40	121
330	2	3	10	1	8	0.48	166	141	15.3	4.34	0.81	109
331	2	3	10	1	9	0.68	138	296	11.0	3.06	0.78	106
332	2	3	10	1	10	0.57	108	273	13.0	2.01	0.88	89

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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